

ELEMENTS
OF THE
THEORY AND PRACTICE
OF
CHYMISTRY.

TRANSLATED from the FRENCH of

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Page 87, line 4. read Procefs III.

— 89, line 3. for *liver* read *liquor*.

— 129, line 1. read Part I.

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S E C T I O N I I.

Of Operations on METALS.

C H A P. I.

Of GOLD.

P R O C E S S I.

To separate Gold, by Amalgamation with Mercury, from the earths and stones with which it is found mixed.

R Educe the earths and stones containing gold into powder. Put it into a little wooden tray; dip this tray in water, gently shaking and its contents. The water will become muddy,
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by taking up the earthy parts of the ore. Continue washing it in this manner till the water cease to appear turbid. Upon the ore thus washed pour strong vinegar, having first dissolved therein, by the help of heat, about a tenth part of its weight of alum. The powder must be quite drenched and covered with this liquor, and so left to stand for twice twenty four hours.

Decant the vinegar, and wash your powder with warm water, till the last that comes off hath no taste: then dry it, and put it into an iron mortar, with four times its weight of quicksilver: triturate the whole with a heavy wooden pestle, till all the powder be of a blackish colour: then pour in a little water, and continue rubbing for some time longer. More earthy and heterogeneous particles will be separated from the metalline parts by means of this water, which will look dirty: it must then be decanted, and more fair water added. Repeat this several times; then dry what remains in the mortar with a sponge, and by the help of a gentle heat: you will find it an amalgam of the mercury with the gold.

Put this amalgam into a chamoy bag: tie a knot on its neck, and squeeze it hard between your fingers, over some wide-mouthed vessel; there will issue through the pores of the leather numberless little jets of mercury, forming a sort of shower, that will collect into large globules in the vessel placed underneath. When you can force out no more mercury by this means, open the bag, and in it you will find the amalgam freed from the superfluous mercury; the gold retaining only about as much thereof as nearly equals itself in weight.

Put this amalgam into a glass retort; set this retort in the sand bath of a reverberating furnace; cover it quite over with sand; apply a glass receiver half full of water, so that the nose of the retort may be under the water. The receiver need not be

PRACTICE OF CHYMISTRY.

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be luted to the retort. Give a gradual heat, and raise the fire till drops of the sublimed mercury appear in the neck of the retort, and fall into the water with a hissing noise. If you hear any noise in the retort, slacken your fire a little. Lastly, when you observe that, though you raise the fire still higher than before, nothing more will come over, take out your retort, break it, and there you will find the gold, which must be melted in a crucible with borax.

OBSERVATIONS.

Gold is a perfect metal, which can by no means be deprived of its phlogiston, and on which few, even of the most powerful chymical solvents, have any effect: and therefore it almost always hath its metalline form when found in the earth; from which it may sometimes be separated by simple solution. The gold dust found in the sands of certain rivers is of this kind. When it resides in stones, or tenacious earths, it may be extracted by the process here delivered; to wit, by amalgamation, or combination of mercury with the gold. Mercury is incapable of uniting with any earthy substances, not even with the metallic earths, when they are deprived of their phlogiston, and consequently have not the metalline form.

Hence it follows that when mercury is triturated with particles of gold, of earth, and of stone, mingled together, it unites with the gold, and separates it from those heterogeneous matters. Yet, if there be along with the gold any other metal, in its metalline form, except iron, the mercury will amalgamate with that also. This often happens to silver, which being a perfect metal as well as gold, is for that reason sometimes dug up in its metalline form, and even incorporated with gold. When this is the case, the mass that remains in the retort, after

abstracting the mercury of the amalgama, is a compound of gold and silver, which are to be separated from each other by the methods we shall give for that purpose. The present process is therefore applicable to silver as well as gold.

Sometimes gold is intimately combined with such mineral matters as hinder the mercury from acting upon it. In that case the mixed mass must be roasted before you proceed to amalgamation: for if the matters be volatile, such, for instance, as antimony or arsenic, the fire will carry them off; so that after roasting the amalgamation will succeed. But sometimes these matters are fixed, and require fusion; if so, recourse must be had to some particular methods, which we shall describe when we come to treat of silver, as these two perfect metals are to be treated in the same manner.

Ores containing gold must be washed before an amalgam is attempted; that the metalline parts, being freed from the numerous particles of earth with which they are encompassed, may the more readily incorporate with the mercury. Besides, it is the property of mercury to take the form of a dark unmetallic powder, after being long rubbed with other matters, so that it cannot be easily distinguished from the particles of earth. And hence, if you still continue to grind the matters together, after the amalgamation is completed, and wash them again and again, the water that comes off will always look turbid, being impregnated with some particles of the amalgam. This is easily proved: for if you let the turbid water settle, and distil the sediment, you will obtain quicksilver from it.

The ore is to be steeped in vinegar charged with alum, in order to cleanse the surface of the gold, which is often covered with a thin coat of earth that obstructs the amalgamation.

Great care must be taken that the mercury employed in this operation be very pure. If it be adulterated

dulterated with any metallic substance, it must be freed therefrom by the methods which we shall propose in their proper place.

The way of separating mercury from gold is founded on the different properties of these two metallic substances; the one being exceedingly fixed, and the other very volatile. The union which mercury contracts with the metals is not intimate enough, to give the new compound which results therefrom all the properties of either of the two united substances; at least so far as concerns their degrees of fixity and volatility. Hence it comes that, in our amalgam, the gold communicates but very little of its fixity to the mercury, and the mercury communicates to the gold but very little of its volatility. Yet if the mercury be distilled off with a much greater degree of heat than is necessary to elevate it, a pretty considerable quantity of gold will most certainly be carried up along with it.

It is also of consequence, on another account, that the fire be duly governed on this occasion. For if too great a degree of heat be applied, and the fire afterwards lowered, the water in the receiver, which covers the nose of the retort, will rise into its body, break it to pieces, and spoil the operation.

The cause of this phenomenon depends on the property which air possesses of rarefying with heat and condensing with cold, joined to its weight. As soon as the retort is acted on by a less degree of heat than acted on it the instant before, the air contained therein is condensed, and leaves a *vacuum*, which the external air, by virtue of its weight, tends to occupy; but, the orifice of the retort being under water, the external air can no way gain admittance, but by pushing in before it the water which intercepts its passage. This caution, as we observed above, must be applied to all distillations, where the vessels are disposed as they are in this.

Care must also be taken that the nose of the retort be not placed too deep under water : for as the neck grows very warm during the operation, because the degree of heat required to raise mercury is about three times greater than that which raises water, it may easily be broken by the contact of the cold water in the receiver.

This method of extracting gold and silver from their ores, by amalgamation with mercury, is not to be absolutely depended on as a sure proof of the quantity of those metals that may be contained in the earth assayed by this means : for some small part of the amalgam is always lost in washing it ; and moreover, the mercury, when squeezed through chamoy, always carries with it a small portion of gold. So that if you desire to know more exactly, by this method, the quantity of gold or silver contained in any earth, the amalgam must not be squeezed through chamoy, but distilled altogether. Much the surest method of making an accurate assay is that by fusion and scorification, which we shall describe under the head of silver.

In some countries, and especially in America, the method of amalgamation is used for extracting gold and silver in large quantities, from the matrices which contain them in their metalline form. Agricola and other metallurgists have described the machines by means whereof such amalgamations are managed.

PRACTICE OF CHYMISTRY.

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PROCESS II.

To dissolve Gold in Aqua regis, and by that means to separate it from Silver. Aurum Fulminans, Aurum Fulminans reduced.

TAKE gold that is perfectly pure, or alloyed with silver only. Reduce it to little thin plates, by hammering it on an anvil. If it be not sufficiently tough, heat it till it be red in a moderate, clear fire, quite free from smoking coals, and then let it cool gradually, which will restore its ductility.

When the plates are thin enough, make them red hot once more, and cut them into small bits with a pair of sheers. Put these bits into a tall, narrow-mouthed cucurbit, and pour on them twice their weight of good *Aqua regis*, made of one part sal ammoniac, or spirit of salt, and four parts spirit of nitre. Set the cucurbit in a sand-bath moderately heated, stopping its orifice slightly with a paper coffin, to prevent any dirt from falling in. The *aqua regis* will presently begin to smoke. Round the little bits of gold will be formed an infinite number of small bubbles, which will rise to the surface of the liquor. The gold will totally dissolve, if it be pure, and the solution will be of a beautiful yellow colour: if the gold be alloyed with a small quantity of silver, the latter will remain at the bottom of the vessel in the form of a white powder. If the gold be alloyed with much silver, when the gold is dissolved the silver will re-
tain

ELEMENTS OF THE

tain the form of the little metalline plates put into the vessel.

When the dissolution is completed, gently pour off the liquor into another low, wide-mouthed, glass cucurbit, taking care that none of the silver, which lies at the bottom in the form of a powder, escape with the liquor. On this powder of silver pour as much fresh *aqua regis* as will cover it entirely; and repeat this till you are sure that nothing more can be taken up by it. Lastly, having decanted the *aqua regis* from the silver, wash the silver with a little spirit of salt weakened with water, and add this spirit of salt to the *aqua regis* in which your gold is dissolved. Then to the body containing these liquors fit a head and a receiver, and distill with a gentle heat, till the matter contained in the cucurbit become dry.

OBSERVATIONS.

It is certain that *aqua regis* is the true solvent of gold, and that it does not touch silver: so that if the gold dissolved in it were alloyed with silver, which is often the case, the two metals would by this means be pretty accurately separated from each other. But if you desire to obtain from this solution a gold absolutely pure, you must free it, before you dissolve it, from every other metallic substance but silver; because *aqua regis* acts upon most of the other metals and the semi-metals. We shall shew under the head of silver, as we promised before, how to purify a mass of gold and silver from every other metallic alloy. Thither also we refer the common parting assay performed by means of *aqua fortis*: because in that operation the silver is dissolved, and not the gold.

If the gold put to dissolve in *aqua regis* be pure, the dissolution is easily and readily effected. But if on the contrary it be alloyed with silver, the *aqua*

regis

regis finds more difficulty in dissolving it. Nay, if the silver exceed the gold in quantity, the dissolution will not take place at all, for the reasons adduced in our Theoretical Elements; of which we shall speak more fully when we come to treat of the parting assay.

In the process we directed the gold to be dissolved in a tall body. This precaution is necessary to prevent the loss of some part thereof: for it is the property of *aqua regis* to carry off along with it some of the gold, especially when there is any sal ammoniac in its composition, if the vessel be heated while the dissolution is going on, or if the *aqua regis* be very strong. Yet it is proper to make use of *aqua regis* that is too strong rather than too weak: for if it prove too strong, and be observed not to act upon the metal for that reason, it is easy to weaken it, by gradually adding small quantities of pure water, till you perceive it begin to act with vigour. This is a general rule regarding all metallic dissolutions in acids.

When the solution of gold is evaporated to dryness, if you desire to reduce into a mass the gold dust left at the bottom of the cucurbit, you must put it into a crucible, and cover it with pulverized borax, mixed with a little nitre and calcined wine-stones; then cover the crucible close, heat it with a moderate fire, which must be afterwards increased so as to melt the contents. At the bottom of the crucible you will find a lump of gold, over which the salts you added will be as it were vitrified. These salts are added chiefly to promote the fusion of the metal.

The gold may, if you will, be separated from its solvent without evaporating the solution as above directed. You need only mix with the solution a fixed or volatile alkali by little and little, till you see no more precipitate fall, and then let the liquor stand to settle, at the bottom of which you will find

a sediment: filter the whole, and dry what is left on the filter.

Both fixed and volatile alkalis possessing, as hath been frequently repeated, a greater affinity with acids than metallic substances have, they precipitate the gold, and separate it from the acids in which it is dissolved: but it is of great consequence to take notice that, if you attempt to melt this precipitated gold in a crucible, it will fulminate as soon as it feels the heat, with such a terrible explosion, that, if the quantity be at all considerable, it may prove fatal to the operator: even rubbing it a little hard will make it blow up. This preparation is therefore called *aurum fulminans*.

Hitherto no satisfactory explanation hath been given of this phenomenon. Some chymists considering that, in the precipitation of the gold, a nitre is regenerated by the union of the alkali with the nitrous acid which enters into the composition of the *aqua regis*, imagine that some of this regenerated nitre, combining with the precipitated gold, takes fire and detonates, either by means of some small portion of phlogiston that may be contained in the alkali, or by means of that which constitutes the gold itself. But, in the first place, it is well known that fixed alkalis do not contain phlogiston enough to make nitre detonate. Indeed, if a volatile alkali be employed in the precipitation, a nitrous ammoniacal salt will be formed, containing phlogiston enough to be capable of detonating without the concurrence of any additional phlogiston: but this detonation of the nitrous ammoniacal salt is not to be compared, as to the violence of its effects, with the fulmination of gold. Besides, we do not find that gold precipitated by a volatile alkali explodes with greater force than that precipitated by a fixed alkali. As for the gold, it is certain that it suffers no decomposition at all by fulminating. When fulminated under a glass bell, in

such

Such small quantities as not to endanger the operator, the gold is found scattered about under the bell in very fine particles, without having undergone any alteration.

Others have fancied this fulmination of the gold to be nothing but the decrepitation of the sea-salt that is regenerated, in the precipitation of the metal, by the fixed alkali uniting with the acid of sea-salt which makes part of the *aqua regis*. But to this it may be said, that gold precipitated by a volatile alkali fulminates as violently as that precipitated by a fixed alkali; and yet no sea-salt can be formed in the liquor by the addition of a volatile alkali, but only a sal ammoniac which has not the property of decrepitating. Moreover, there is no comparison, as to the effects, between the decrepitation of sea-salt and the fulmination of gold.

Nor, lastly, can this fulmination be attributed, as it is by some, to the effort made by the salts to escape from amidst the particles of gold, in which they are supposed by them to be imprisoned: for then we might deprive this gold entirely of its fulminating quality by only boiling it in water, and so washing off all the saline particles, which probably adhere to its surface only. It is plain there is great room for very beautiful discoveries on this subject. In Walerius's Mineralogy we find some observations that may throw a little light on the point before us.

“The quantity, says he, of fulminating gold precipitated exceeds that of the gold dissolved: if the *aqua regis* be made with sal ammoniac the explosion will be stronger; it will also be more violent if the solution be precipitated with a volatile alkali, than if a fixed alkali be used for that purpose.”

One of the speediest and easiest methods to deprive this gold of its fulminating quality, is to grind in a mortar twice as much flowers of sulphur as

you

you have gold to reduce, mixing your fulminating gold therewith by little and little as you grind them together; then to put the mixture into a crucible, and heat it just enough to melt the sulphur. Part of the sulphur will be dissipated in vapours, and the rest will burn away. When it is quite consumed, encrease the fire so as to make the crucible red-hot. When you perceive no more smell of sulphur, pour on the gold a little borax, previously melted in another crucible with a fixed alkali, as calcined wine-lees, or nitre fixed with tartar; and then raise the fire sufficiently to make the whole flow. After the fusion is completed you will find a button of gold at the bottom of the crucible under the salts.

Fulminating gold may also be reduced by pouring on it a sufficient quantity of fixed alkali reduced to a liquor, or of oil of vitriol, evaporating all the moisture, and gradually throwing what remains, mixed up with some pinguious matter, into a crucible kept red-hot in a furnace. The reason why these substances deprive the gold of its fulminating quality depends on the causes that produce the fulmination.

Gold may also be separated from *aqua regis*, and precipitated by the means of several metallic substances that have a greater affinity, either with *aqua regis*, or with one of the two acids that compose it. Mercury is one of the fittest for this purpose. On dropping a solution of mercury in the nitrous acid by little and little into a solution of gold, the mixture becomes turbid, and a precipitate is formed. Continue dropping in more of the solution of mercury till no more precipitate falls; then let the liquor stand to settle, and at the bottom of it you will find a sediment, which is the precipitated gold: pour off the liquor by inclination, and wash the precipitate with fair water.

Mercury

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Mercury hath a greater affinity with the marine than with the nitrous acid. The affinity which mercury hath with the marine acid is also greater than that of gold with the marine acid; for unless this acid be associated either with the nitrous acid, or at least with a certain proportion of phlogiston, it will not dissolve gold. Hence it comes that when a solution of mercury in the nitrous acid is dropped into a solution of gold in *aqua regis*, the mercury unites with the acid of sea-salt, which is an ingredient in the *aqua regis*: but the marine acid cannot on this occasion join the mercury, without deserting the gold and the nitrous acid with which it was united; and then the gold, which cannot be kept in solution by the nitrous acid alone, is forced to quit its solvent and precipitate. The liquor, therefore, that now floats over the gold thus precipitated, must contain mercury united with the acid of sea-salt: and in fact it yields a true corrosive sublimate, which is known to be a combination of mercury with the marine acid.

Mercury dissolved in spirit of nitre is employed to procure the precipitation we are speaking of; because metallic substances, when so comminuted by an acid, are much fitter for such experiments than when they are in a concrete form.

Gold precipitated in this manner by a metallic substance doth not fulminate.

PROCESS III.

To dissolve Gold by Liver of Sulphur.

MIX together equal parts of common brimstone, and a very strong fixed alkali; for instance, nitre fixed by charcoal. Put them in a crucible, and melt the mixture, stirring it from time to time with a small rod. There is no occasion to make the fire very brisk; because the sulphur facilitates the fusion of the fixed alkali. Some sulphureous vapours will rise from the crucible; the two substances will mix intimately together, and form a reddish compound. Then throw into the crucible some little pieces of gold beat into thin plates, so that the whole do not exceed in weight one third part of the liver of sulphur: raise the fire a little. As soon as the liver of sulphur is perfectly melted, it will begin to dissolve the gold with ebullition; and will even emit some flashes of fire. In the space of a few minutes the gold will be entirely dissolved, especially if it was cut and flattened into small thin leaves.

OBSERVATIONS.

The process here delivered is taken from M. Stahl. The design of that ingenious chymist's enquiry was to discover how Moses could burn the golden calf, which the Israelites had set up and worshipped while he was on the mount; how he could afterwards reduce that calf to powder, throw it into the water which the people used, and make all who had apostatized drink thereof, as related in the Book of Exodus.

M. Stahl

M. Stahl, having first observed that gold is absolutely inalterable and indestructible by the force of fire alone, be it ever so violent, concludes, that without a miracle Moses could not possibly perform the above-mentioned operations on the golden calf, any way but by mixing with the gold some matter qualified to alter and dissolve it. He then takes notice that pure sulphur does not act upon gold at all, and that many other substances, which are thought capable of dividing and dissolving it, cannot however do it so completely as is necessary to render that metal susceptible of the effects related. He then gives the method of dissolving it by liver of sulphur described in the process.

Liver of sulphur dissolves likewise all the other metals: but M. Stahl observes that it attenuates gold more than any other metallic substance, and unites with it much more intimately than with the rest. This appears from what happens, on attempting to dissolve in water any of the mixts resulting from the union of another metal with liver of sulphur: for then the metal separates, and appears in the form of a powder or fine calx; whereas, when gold is united with the liver of sulphur, the whole compound dissolves in water so perfectly, that the gold even passes with the liver of sulphur through the pores of filtering paper.

If an acid be poured into a solution of this combination of gold with liver of sulphur, the acid unites with the alkali of the *hepar*, and the gold falls to the bottom of the liquor along with the sulphur, which doth not quit it. The sulphur thus precipitated with the gold is easily carried off by a slight torrefaction, after which the gold remains exceedingly comminuted. The sulphur of this compound may also be destroyed by torrefaction, without the trouble of a previous solution and precipitation, and then also the gold remains so attenuated as to be miscible with liquors, and floats on them,

or swims in them, in such a manner that it may easily be swallowed with them in drinking. From all this M. Stahl concludes there is great reason to believe it was by means of the liver of sulphur that Moses divided, and in a manner calcined, the golden calf, so that he could mingle it with water, and make the Israelites drink it.

P R O C E S S IV.

To separate Gold from all other metallic Substances by means of Antimony.

HAVING put the gold you intend to purify into a crucible, set it in a melting furnace, cover it, and make the gold flow. When the metal is in fusion cast upon it, by a little at a time, twice its weight of pure crude antimony in powder, and after each projection cover the crucible again immediately: this done keep the matter in fusion for a few minutes. When you perceive that the metallic mixture is perfectly melted, and that its surface begins to sparkle, pour it out into a hollow iron cone, previously heated, and smeared on the inside with tallow. Immediately strike with a hammer the floor on which the cone stands; and when all is cold, or at least sufficiently fixed, invert the cone and strike it: the whole metallic mass will fall out, and the under part thereof, which was at the point of the cone, will be a regulus more or less yellow as the gold was more or less pure. On striking the metallic mass the regulus will freely part from the sulphureous crust at top.

Return this regulus into the crucible, and melt it. Less fire will do now than was required before. Add the same quantity of antimony, and proceed

as at first. Repeat the same operation a third time, if your gold be very impure.

Then put your regulus into a good crucible, much larger than is necessary to hold it. Set your crucible in a melting furnace, and heat the matter but just enough to make it flow, with a smooth, brilliant surface. When you find it thus conditioned, point towards it the nose of a long-snouted pair of bellows, and therewith keep gently and constantly blowing. There will arise from the crucible a considerable smoke, which will abate greatly when you cease to blow, and increase as soon as you begin again. You must raise the fire gradually as you approach towards the end of the operation. If the surface of the metal lose its brilliant polish, and seem covered with a hard crust, it is a sign the fire is too weak; in which case it must be increased, till the surface recover its shining appearance. At last, when no more smoke rises, and the surface of the gold looks neat and greenish, cast on it, by little and little, some pulverized nitre, or a mixture of nitre and borax. The matter will swell up. Continue thus adding more nitre gradually, till no commotion is thereby produced in the crucible; and then let the whole cool. If you find, when the gold is cold, that it is not tough enough, melt it over again; when it begins to melt cast in the same salts as before; and repeat this till it be perfectly ductile.

OBSERVATIONS.

Antimony is a compound, consisting of a semi-metallic part united with about a fourth part of its weight of common sulphur. It appears, in the ninth column of the table of affinities, that all the metals, mercury and gold excepted, have a greater affinity than the reguline part of antimony with sulphur. If therefore gold, adulterated with a

mixture of copper, silver, or any other metal, be melted with antimony, those metals will unite with the sulphur of the antimony, and separate it from the reguline part, which being thus set free will combine and be blended with the gold. These two metallic substances, forming a mass far heavier than the other metals mixed with the sulphur, fall together to the bottom of the crucible in the form of a regulus, while the others float over them like a sort of scoria or slag : and thus the gold is freed from all alloy but the reguline part of the antimony.

As all the other metals have a great affinity with sulphur, and gold is the only one that is capable of resisting its action, one would think sulphur alone might be sufficient to free it from the metals combined with it, and that it would therefore be better to employ pure sulphur, in this operation, than to make use of antimony; the reguline part of which remaining united with the gold requires another long and laborious operation to get rid of it.

Indeed, strictly speaking, sulphur alone would be sufficient to produce the desired separation: but it is proper to observe that, as sulphur alone is very combustible, most of it would be consumed in the operation before it could have an opportunity to unite with the metallic substances; whereas when it is combined with the regulus of antimony, it is thereby enabled to bear the action of the fire much longer without burning, and consequently is much fitter for the purpose in question. Besides, if we were to make use of pure sulphur, a great part of the gold, which is kept in perfect fusion, and its precipitation facilitated, by the regulus of antimony, would remain confounded with the sulphureous scoria.

Nevertheless, seeing the metals with which gold is alloyed cannot be separated from it by antimony,

but

but that a quantity of regulus proportioned to the quantity of the metals so separated will unite with the gold, and that the more regulus combines with the gold, the more tedious, chargeable, and laborious will the operation prove, this consideration ought to have some influence in directing our process. Therefore, if the gold be very impure, and worse than sixteen carats, we must not mix it with crude antimony alone, but add two drams of pure sulphur for every carat the gold wants of sixteen, and lessen the quantity of antimony in proportion to that of the real gold.

It is necessary to keep the crucible close covered, after mixing the antimony with the gold, to prevent any coals from falling into it: for, if that should happen, the melted mass would puff up considerably, and might perhaps run over.

The inside of the cone, into which you pour the melted metallic mass, must be greased with tallow, to prevent its sticking thereto, and that it may come easily out. Striking the floor, on which the cone with the melted metal stands, helps the precipitation and descent of the regulus of gold and antimony to the bottom of the cone.

Less fire is requisite to melt this compound regulus, in order to add fresh antimony, than was necessary before the gold was mixed with the reguline part of the antimony; because this metallic substance, being much more fusible than gold, promotes its melting. The antimony is mixed with the gold by repeated projections, that the separation of the metals may be accomplished with the greater ease and accuracy. Yet the operation might be successfully performed, by putting in all the antimony at once, and with one melting only.

The metalline mass found at the bottom of the cone after all these operations, is a mixture of gold with the reguline part of the antimony. All the rest of the process consists only in separating this reguline

line part from the gold. As gold is the most fixed of all metals, and as the regulus of antimony cannot bear the violence of fire without flying off in vapours, nothing more is necessary for this purpose but to expose the compound, as directed in the process, to a heat strong enough, and long enough continued, to dissipate all the regulus of antimony. This semi-metal exhales in the form of a very thick white smoke. It is proper to blow gently into the crucible during the whole operation; because the immediate contact of the fresh air incessantly thrown in promotes and considerably increases the evaporation: and this is a general rule applicable to all evaporations.

The fire must be gradually raised as the regulus of antimony is dissipated, and the operation draws towards an end; because the mixed mass of regulus of antimony and gold becomes so much the less fusible as the proportion of the regulus is lessened. Though the regulus of antimony be separated from the gold in this operation, because the latter is of such a fixed nature that it cannot be volatilized by the degree of fire which dissipates the regulus; yet, as the regulus is very volatile, it will undoubtedly carry up some of the gold along with it, especially if you hurry on the evaporation too fast, by applying too great a degree of fire, by blowing too briskly into the crucible, and still more if you evaporate your mixture in a broad flat vessel instead of a crucible. All these things must therefore be avoided, if you would lose no more gold than you needs must.

However, unless the evaporation be carried to the utmost, by the means above pointed out, a small portion of the regulus of antimony will always remain combined with the gold, which defends it from the action of the fire. This small portion of regulus hinders the gold from being perfectly pure and ductile. In order, therefore;

to consume and scōrify it, we cast nitre into the crucible when we perceive it to emit no more white vapours.

We know that nitre has the property of reducing all metallic substances to a calx, gold and silver excepted; because it deflagrates with the phlogiston to which their metalline form is owing: but as this accension of the nitre occasions a tumid effervescence, care must be taken to throw it in but by little and little at a time; for if too much be projected at once the melted matter will run over.

This operation might be considerably abridged by taking advantage of the property which nitre possesses of thus consuming the phlogiston of metallic substances; as by means thereof we might destroy all the regulus of antimony incorporated with the gold, without having recourse to a long and tedious evaporation. But then we should at the same time lose a much greater quantity of gold, by reason of the tumult and ebullition which are inseparable from the detonation of nitre. On the whole, therefore, if nitre be made use of to purify gold, great care must be taken to apply but very little of it at a time.

All the silver that was mixed with the gold, and indeed a little of the gold itself, remains confounded with the sulphureous scoria, which floats upon the golden regulus after the addition of the antimony: we shall shew in the chapter on silver how these two metals are to be separated from the sulphur.



C H A P. II.

Of SILVER.

P R O C E S S I.

To separate silver from its ore, by means of scorification with lead.

BEAT to powder in an iron mortar the ore from which you mean to separate the silver, having first roasted it well in order to free it from all the sulphur and arsenic that it may contain. Weigh it exactly : then weigh out by itself eight times as much granulated lead. Put one half of this lead into a test, and spread it equally thereon : upon this lead lay your ore, and cover it quite over with the remaining half of the lead.

Place the test thus loaded under the further end of the muffle in a cupelling furnace. Light your fire, and increase it by degrees. If you look thro' one of the apertures in the door of the furnace you will perceive the ore, covered with calcined lead, swim upon the melted lead. Presently afterwards it will grow soft, melt, and be thrown towards the sides of the vessel, the surface of the lead appearing in the midst thereof bright and shining like a luminous disc : the lead will then begin to boil, and emit fumes. As soon as this happens, the fire must be a little checked, so that the ebullition of the lead

lead may almost entirely cease, for about a quarter of an hour. After this it must be excited to the degree it was at before, so that the lead may begin again to boil and smoke. Its shining surface will gradually lessen, and be covered with *scoriae*. Stir the whole with an iron hook, and draw in towards the middle what you observe towards the sides of the vessel; to the end that, if any part of the ore should still remain undissolved by the lead, it may be mixed therewith.

When you perceive that the matter is in perfect fusion, that the greatest part of what sticks to the iron hook, when you dip it in the melted matter, separates from it again, and drops back into the vessel; and that the extremity of this instrument when grown cold, appears varnished over with a thin, smooth, shining crust; you may look on these as marks that the business is done, and the more uniform and evenly the colour of the crust is, the more perfect may you judge the scorification to be.

Matters being brought to this pass, take the test with a pair of tongs from under the muffle, and pour its whole contents into an iron cone, first heated and greased with tallow. This whole operation lasts about three quarters of an hour. When all is cold, the blow of a hammer will part the regulus from the scoria; and as it is not possible, how perfect soever the scorification be, to avoid leaving a little lead containing silver in the scoria, it is proper to pulverise this scoria, and separate therefrom whatever extends under the hammer, in order to add it to the regulus.

OBSERVATIONS.

Silver, as well as gold, is often found quite pure, and under its metalline form, in the bowels of the earth; and in that case it may be separated from the

the stones or sand, in which it is lodged, by simple washing, or by amalgamation with mercury, in the same manner as before directed for gold. But it also happens frequently that silver is combined in the ore with other metallic substances and minerals, which will not admit of this process, but force us to employ other methods of separating it from them.

Sulphur and arsenic are the substances to which silver and the other metals usually owe their mineral state. These two matters are never very closely united with silver; but may be pretty easily separated from it by the action of fire, and the addition of lead. If arsenic be predominant in a silver ore, it will unite with the lead by the help of a pretty moderate heat, and quickly convert a considerable quantity thereof into a penetrating fusible glass, which has the property of scorifying with ease all substances that are capable of scorification.

When sulphur predominates, the scorification proceeds more slowly, and doth not always succeed; because that mineral combined with lead lessens its fusibility, and retards its vitrification. In this case part of the sulphur must be dissipated by roasting: the other part unites with the lead; and that, being rendered lighter by this union, floats on the rest of the mixture, which chiefly contains the silver. At last the joint action of the air and of the fire, dissipates the portion of sulphur that had united with the lead: the lead vitrifies and reduces to a scoria whatever is not either silver or gold: and thus the silver being disentangled from the heterogeneous matters with which it was united, one part thereof being dissipated and the other vitrified, combines with the portion of lead which is not vitrified, and falls through the scoria, which to favour its descent must be in perfect fusion.

The whole process, therefore, consists of three distinct operations. The first is roasting, which
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dissipates some of the volatile substances found united with the silver: the second is scorification, or the vitrification of the fixed matters also united with the silver, such as sand, stones, metals, &c. and the third is precipitation, or the separation of the silver from the scoria. The two first are, as hath been shewn, preparatives for the last, and indeed produce it.

As every thing we said concerning gold, when we treated of the process of amalgamation, is to be applied to silver, which may be extracted by the same method when it is in its metalline form; in the same manner all we now advance touching the method of extracting silver by scorification, when it is depraved with a mixture of heterogeneous matters, is equally applicable to gold in the same circumstances: and indeed silver almost always contains more or less gold naturally.

In the process we directed that the ore should be pulverized before it be exposed to the fire, with a view to enlarge its surface, and by that means facilitate the action of the lead upon it, as well as the evaporation of its volatile parts.

We recommended the precaution of slackening the fire a little at the beginning of the operation, only to prevent the lead from being too hastily converted into litharge, lest it should penetrate and corrode the test before it had wholly dissolved the ore: but if we were perfectly certain of the vessel's being so good as to be in no danger of penetration by the lead, this precaution would be needless.

It is proper to add eight parts of lead for one of ore; though so much is not always absolutely necessary, especially when the ore is very fusible. The success of this operation depends chiefly on the completeness of the scorification; and therefore the addition of more lead than enough is attended with no inconvenience: for, as it always promotes the scorification, it can never do any harm.

If the ore be mixed with such earthy and stony parts as cannot be separated from it by washing, it is the more difficult of fusion, even though the stones should be such as are most disposed to vitrify; because the most fusible earths and stones are always less so than most metallic substances. In that case it will be necessary, for effecting the scorification, to mix thoroughly with the pulverized ore an equal quantity of glass of lead, to add twelve times as much granulated lead, and then to proceed as directed for a fusible ore; exposing the mixture to a degree of fire strong enough, and long enough kept up, to give the scoria all the properties above required as signs of a perfect scorification.

Silver ore is sometimes mixed with pyrites, and the ore of arsenic, or cobalt, which also make it refractory. As the pyrites contain a large quantity of sulphur, which is very volatile as well as arsenic; in this case it is proper to begin with freeing the ore from these two extraneous substances. This is easily done by roasting: only be sure, when you first expose the ore to the heat, to cover the vessel in which you roast it, for some minutes, with an inverted vessel of the same width; because such sorts of ore are very apt to fly when they first feel the heat.

After this uncover it, and leave it exposed to the fire till no more sulphureous or arsenical matters rise. Then mix it with the same quantity of glass of lead as we ordered for ores rendered refractory by the admixture of earths or stones, and proceed in the same manner.

It is the more necessary to roast silver ore infected with sulphur and arsenic, because, as sulphur obstructs the fusion of lead, it cannot but do hurt, and protract the operation; and arsenic does mischief, on the other hand, by scorifying a very great quantity of lead too hastily.

When

When the sulphur and arsenic are dissipated by roasting, the ore must be treated like that which is rendered refractory by stony and earthy matters; for as the pyrites contain much iron, there remains, after the sulphur is evaporated, a considerable quantity of martial earth, which is difficult to scori- fy. The pyrites, as well as the cobalts, contain moreover an unmetallic earth, which is hard to fuse.

The general rule therefore is, when the ore is rendered refractory by any cause whatever, to mix it with glass of lead, and to add a larger quantity of granulated lead. Yet some ores are so refractory that lead alone will not do the business, and recourse must be had to some other flux. That which is fittest for the present purpose is the *black flux*, composed of one part of nitre and two parts of tartar deflagrated together. The phlogiston contained in this quantity of tartar is more than sufficient to alkalize the nitre. This flux therefore is nothing more than nitre alkalized by tartar, mixed with some of the same tartar that hath not lost its phlogiston, and is only reduced to a sort of coal.

The *white flux* is also very fit to promote fusion; but on this occasion the black flux is preferable, because the phlogiston of the black flux prevents the lead from being too soon converted to litharge, and so gives it time to dissolve the metallic matters. The white flux, which is the result of equal parts of tartar and nitre alkalized together, being no more than an alkali destitute of phlogiston, or containing but very little, doth not possess this advantage.

If silver should be combined in the ore with iron in its metalline state, which however does not commonly happen; then, in order to separate them, the iron must be deprived of its phlogiston, and converted to a *crocus* before the mixed mass be melted.

melted with lead ; which may be done by dissolving it in the vitriolic acid, and then evaporating the acid.

We are necessitated to make use of this contrivance, because iron in its metalline form cannot be dissolved either by lead or by the glass of lead ; but when it is reduced to a calx, litharge unites with it and scorifies it.

If you have not at hand the utensils necessary for performing the operation we have been describing in a test, and under the muffle ; or if you have a mind to work on a greater quantity of ore at a time, you may make use of a crucible for the purpose, and perform the operation in a melting furnace.

In this case the ore must be prepared, as above directed, according to its nature, and mixed with a proper quantity of lead and glass of lead ; the whole put into a good crucible, leaving two thirds thereof empty, and covered with a mixture of sea-salt and a little borax, both very dry, to the thickness of a full half inch.

This being done, set the crucible in the midst of a melting furnace, raise the coals quite to the lip of the crucible ; light the fire ; cover the furnace with its dome ; but do not urge the fire more than is necessary to bring the mixture to perfect fusion : leave it thus in fusion for a good quarter of an hour ; stir the whole with a bit of strong iron wire ; then let it cool ; break the crucible, and separate the regulus from the scoria.

The salts added on this occasion are fluxes, and their use is to procure a perfect fusion of the scoria.

If the melted matters be left exposed to the fire, either in a test, or in a crucible, longer than is above prescribed, the portion of lead, that hath united and precipitated with the silver, will at last vitrify, and at the same time scorify all the alloy with which that metal may be mixed. But as

there

there are no vessels that can long endure the action of litharge, without being pierced like a sieve, some of the silver may escape through the holes or fissures of the vessel, and so be lost. It is better therefore to complete the purification of your silver by the operation of the cupel, the description of which follows.

PROCESS II.

The refining of silver by the Cupel.

TAKE a cupel capable of containing one third more matter than you have to put into it: set it under the muffle of a furnace, like that described in our theoretical elements, as peculiarly appropriated to this sort of operation. Fill the furnace with charcoal; light it; make the cupel red-hot, and keep it so till all its moisture be evaporated; that is, for about a quarter of an hour, if the cupel be made wholly of the ashes of burnt bones; and for a whole hour, if there be any washed wood-ash in its composition.

Reduce the regulus which remained after the preceding operation to little thin plates, flattening them with a small hammer, and separating them carefully from all the adherent scoria. Wrap these in a bit of paper, and with a small pair of tongs put them gently into the cupel. When the paper is consumed the regulus will soon melt, and the scoria, which will be gradually produced by the lead as it turns to litharge, will be driven to the sides of the cupel, and immediately absorbed thereby. At the same time the cupel will assume a yellow, brown, or blackish colour, according to the quantity and nature of the scoria imbibed by it.

When you see the matter in the cupel in a violent ebullition, and emitting much smoke, lower the fire by the methods formerly prescribed. Keep up such a degree of heat only that the smoke which ascends from the matter may not rise very high, and that you may be able to distinguish the colour which the cupel acquires from the scoria.

Increase the fire by degrees, as more and more litharge is formed and absorbed. If the regulus examined by this assay contain no silver, you will see it turn wholly into scoria, and at last disappear. When it contains silver, and the quantity of lead is much diminished, you will perceive little vivid irises, or beautiful rain-bow colours, shooting swiftly along its surface, and crossing each other in many different directions. At last, when all the lead is destroyed, the thin dark skin, that is continually protruded by the lead while it is turning into litharge, and which hath hitherto covered the silver, suddenly disappears; and, if at this moment the fire happen not to be strong enough to keep the silver in fusion, the surface of that metal will at once dart out a dazzling splendour; but, if the fire be strong enough to keep the silver in fusion, though freed from all mixture of lead, this change of colour, which is called its *fulguration*, will not be so perceptible, and the silver will appear like a bead of fire.

These phenomena shew that the operation is finished. But the cupel must still be left a minute or two under the muffle, and then drawn slowly out with the iron hook towards the door of the furnace. When the silver is so cooled as to be but moderately red, you may take the cupel from under the muffle with your little tongs, and in the middle of its cavity you will find an exceeding white bead of silver, the lower part whereof will be unequal, and full of little pits.

OBSERVATIONS.

The regulus obtained by the former process consists altogether of the silver contained in the ore, alloyed with the other metals that happened to be mixed therewith in its mineral state, and a good deal of the lead that was added to precipitate the silver. The operation of the cupel may be considered as the sequel of that process, being intended only to reduce into a scoria whatever is not gold or silver. Lead being of all metals that which vitrifies the most easily, which most promotes the vitrification of the rest, and the only one which, when vitrified, penetrates the cupel, and carries along with it the other metals which it hath vitrified, is consequently the fittest for that purpose. We shall see in its place that bismuth hath the same properties with lead, and may be substituted for it in this operation.

Care must be taken to chuse a cupel of a proper capacity. Indeed it should rather be too big than too little : because the operation is no way prejudiced by an excess in its size ; whereas, if it be too small, it will be overclosed with lead, and at last the litharge, which destroys every thing, will corrode its cavity, and eat holes through the very body of the vessel. Add that the ashes, of which the cupel is made, being once glutted with litharge, absorb it afterwards but slowly, and that the quantity of this vitrified litharge, becoming too great to be contained in the substance of the vessel, exsudes through it, and drops on the floor of the muffle, which it corrodes and renders unequal, and moreover soldiers to it the vessels set thereon. It may be laid down as a general rule for determining the size of the cupel, that it weigh, at least, half as much as the metallic mass to be refined in it.

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It is also of the utmost consequence that the cupel be well dried before the metal be put into it. In order to make sure of this point it must be kept red-hot for a certain time, as is above directed: for though to the sight and to the touch it may appear very dry, it nevertheless obstinately retains a small matter of moisture, sufficient to occasion the loss of some of the metal; which, when it comes to melt, will be thereby spirited up, in the form of little globules, to the very roof of the muffle. The cupels, that stand most in need of an intense heat to dry them, are those chiefly in whose composition wood-ashes are employed: for whatever care be taken to lixiviate those ashes before they are used, they will still retain a little alkaline salt; and that, we know, is very greedy of moisture, will not part intirely with it, but by the means of a violent calcination, and presently re-imbibes it when exposed to the air.

A little phlogiston also may still be left in the ashes of which the cupels are made; and that is another reason for calcining them before they are used. By this means the remaining phlogiston is dissipated, which might otherwise combine with the litharge during the operation, reduce it, and occasion such a ferment in the matter as to make some of it run over: to these inconveniencies, which any remainder of moisture or phlogiston may produce, we must add the cracks and flaws, which are very incident to cupels not perfectly freed from both those matters.

It is of no less importance to the success of this operation, that a due degree of heat be kept up. In the process we have described the marks which shew the heat to be neither too strong nor too weak: when it exceeds in either of these respects may be known by the following signs.

If the fume emitted by the lead rise like a spout to the roof of the muffle; if the surface of the melted-

melted metal be extremely convex, considering the quantity of the mass: if the cupel appear of such a white heat, that the colour communicated thereto by the imbibed scoria cannot be distinguished; all these shew that the heat is too great, and that it ought to be diminished. If, on the contrary, the vapours only hover, as it were, over the surface of the metal; if the melted mass be very flat, considering its quantity; if its ebullition appear but faint; if the *scoria*, that appear like little fiery drops of rain, have but a languid motion; if the scoria gather in heaps, and do not penetrate the cupel; if the metal be covered with it as with a glassy coat; and lastly, if the cupel look dull; these are proofs that the heat is too weak, and ought to be increased.

The design of this operation being to convert the lead into litharge, and to give it sufficient time and opportunity to scorify and carry off with it whatever is not gold or silver; the fire must be kept up to such a degree that the lead may easily be turned into litharge, and yet that litharge not be absorbed too hastily by the cupel, but that a small quantity thereof may all along remain, like a ring, round the melted metal.

The fire is to be gradually increased as the operation draws nearer to its end; for, as the proportion of the lead to the silver is continually lessening, the metallic mass gradually becomes less fusible: while the silver defends the lead mixed with it from the action of the fire, and prevents its being easily converted into litharge.

When the operation is finished, the cupel must still be left under the muffle, till it has imbibed all the litharge, to the end that the bead of silver may be easily taken out: for without this precaution, it would stick so fast as not to be removed, but by breaking off part of the cupel along with it. Care must also be taken to let this bead of silver cool gradually

gradually. and be perfectly fixed, before you draw it from under the muffle ; for, if you expose it at once to the cold air, before it be fixed, it will swell, shoot into sprigs, and even dart out several little grains to a considerable distance, which will be lost.

If the bead appear to have a yellowish tinge, 'tis a sign that it contains a great deal of gold, which must be separated from it by the methods to be hereafter shewn.

It is proper to observe that there is scarce any lead that does not contain some silver : too little perhaps to defray the charges necessary to separate it, yet considerable enough to lead us into an error, by mixing with the silver obtained from an ore, and increasing its weight. And therefore, when the operations above described are applied to the assaying of an ore, in order to know how much silver it yields, it is previously necessary to examine the lead to be used, and to ascertain the quantity of silver it contains, which must be deducted from the total weight of the bead of silver obtained by purifying it in this manner.

Silver may be separated from its ore, and at the same time refined, by the single operation of the cupel, without any previous scorification with lead. In order to do this, you must pound the ore ; roast it, to dissipate all its volatile parts ; mix it with an equal quantity of litharge, if it be refractory ; divide it into five or six parcels, wrapping each in a bit of paper ; weigh out eight parts of granulated lead for one of ore, if it be fusible, and from twelve to sixteen, if it be refractory ; put one half of the lead into a very large cupel under the muffle ; add thereto one of the little parcels of ore, when the lead begins to smoke and boil ; immediately slacken the fire a little ; continue the same degree of heat till you perceive that the litharge formed round the metal, and on its surface, begins to

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look bright ; then raise the fire ; add a fresh parcel of ore ; continue proceeding in the same manner till you have put in all the ore ; then add the remaining half of the granulated lead, and conduct the succeeding part of the operation in the same manner as that of cupelling.

In this operation it is necessary that the fire be not too strongly urged, and that it be diminished every time you add a fresh parcel of ore ; that so the lead and the litharge may have time to dissolve, scorify, and carry off into the pores of the cupel, all the adventitious matters with which your silver may be mixed. Notwithstanding this precaution, when the ore is refractory, there often gathers in the cupel a great quantity of scoria, together also with some of the ore that could not be dissolved and scorified. It is with a view to remedy this inconvenience that the second moiety of the lead is added towards the end, which completes the dissolution and scorification of the whole ; so that by means thereof, no scoria, or very little, is left in the cupel at the end of the operation.

The operation of the cupel is chiefly used to purify silver from the alloy of copper ; because this metal, being more fixed and harder to calcine than other metallic substances, is the only one that remains united with silver and lead, after roasting and scorification with lead. It requires no less than sixteen parts of lead to destroy it in the cupel, and separate it from silver. It melts into one mass with the lead ; and the glass produced by these two metals, deprived of their phlogiston, inclines to a brown or a black colour ; by which appearance chiefly we know that our silver was alloyed with copper.

PROCESS III.

To purify Silver by Nitre.

GRanulate the silver you intend to purify, or reduce it to thin plates; put it into a good crucible; add thereto a fourth part in weight of very dry pulverized nitre, mixed with half the weight of the nitre of calcined wine-lees, and about a sixth part of the same weight of common glass in powder. Cover this crucible with another crucible inverted; which must be of such a size that its mouth may enter a little way into that of the lower one, and have its bottom pierced with a hole of about two lines in diameter. Lute the two crucibles together with clay and Windsor-loam. When the lute is dry, place the crucibles in a melting furnace. Fill the furnace with charcoal, taking care however that the fuel do not rise above the upper crucible.

Kindle the fire, and make your vessels of a middling-red heat. When they are so; take up with the tongs a live coal, and hold it over the hole of the upper crucible. If you immediately perceive a vivid splendour round the coal, and at the same time hear a gentle hissing noise, it is a sign that the fire is of a proper strength; and it must be kept up at the same degree till this phenomenon cease.

Then increase the fire to the degree requisite to keep pure silver in fusion; and immediately after take your vessels out of the furnace. You will find the silver at the bottom of the lower crucible, covered with a mass of alkaline scoria of a greenish colour. If the metal be not rendered perfectly pure

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and ductile by this operation, it must be repeated a second time.

OBSERVATIONS.

The purification of silver by nitre, as well as the process for refining it on the cupel, is founded on the property which this metal possesses of resisting the force of the strongest fire, and the power of the most active solvents, without losing its phlogiston. The difference between these two operations consists wholly in the substances made use of to procure the scorification of the imperfect metals, or semi-metals, that may be combined with the silver. In the former this was obtained by lead, and here it is effected by nitre. This salt, as we have shewn, hath the property of calcining and quickly destroying all metallic substances, by consuming their phlogiston, except the perfect metals, gold and silver, which alone are able to resist its force. This method may therefore be employed to purify gold as well as silver, or indeed both the two mixed together.

In this operation the nitre is gradually alkalized, as its acid is consumed with the phlogiston of the metallic substances. The alkaline salt and pounded glass are added, with a view to promote the fusion of the metalline calxes, as fast as they are formed, and to fix and retain the nitre, which, as we shall presently see, is apt to fly off in a certain degree of heat.

The precaution of covering the crucible with another crucible inverted, which hath only a small hole in its bottom, is designed to prevent any of the silver from being lost in the operation: for when the nitre comes to be acted on by a certain degree of heat, and especially when it deflagrates with any inflammable matter, part of it flies off, and so rapidly too as to be capable of carrying off

with it a good deal of the silver. The little hole left in the covering crucible is necessary for giving vent to the vapours, which rise during the deflagration of the nitre, as they would otherwise open themselves a passage by bursting the vessels. After the operation this vent-hole is found beset with many little particles of silver, which would have been lost if the crucible had not been covered.

If you should observe, during the detonation of the nitre, that a great many vapours issue through the vent-hole with a considerable hissing noise, even without applying the coal, you must take it for a sign that the fire is too brisk, and accordingly check it; else a great deal of the nitre will be dissipated, and with it much silver.

You must observe to take the silver out of the fire as soon as it is in fusion: for if you neglect this, the nitre being entirely dissipated or alkalized, the calxes of the metals destroyed by it may possibly recover a little phlogiston, communicated either by the vapours of the charcoal, or by little bits of coal accidentally falling into the crucible; by which means some portion of those metals being reduced will mix again with the silver, prevent its having the desired degree of purity and ductility, and oblige you to begin the operation afresh.

PROCESS IV.

To dissolve Silver in Aqua Fortis, and thereby separate it from every other metalline Substance. The Purification of Aqua Fortis. Silver precipitated by Copper.

THE silver you intend to dissolve being beaten into thin plates, put it into a glass cucurbit; pour on it twice its weight of good precipitated *aqua fortis*; cover the cucurbit with a piece of paper, and set it on a sand-bath moderately heated. The *aqua fortis* will begin to dissolve the silver as soon as it comes to be a little warm. Red vapours will rise; and from the upper surfaces of the silver there will seem to issue streams of little bubbles, ascending to the top of the liquor, between which and the silver they will form, as it were, a number of fine chains: this is a sign that the dissolution proceeds duly, and that the degree of heat is such as it ought to be. If the liquor appear to boil and be agitated, a great many red vapours rising at the same time, it is a sign that the heat is too great, and should be lessened till it be reduced to the proper degree indicated above: having obtained that, keep it equally up till no more bubbles or red vapours appear.

If your silver be alloyed with gold, the gold will be found, when the dissolution is finished, at the bottom of the vessel in the form of a powder. The solution must now be decanted while it is yet warm: in the powder pour half as much fresh *aqua fortis* as before, and make it boil; again decant this second *aqua fortis*, and repeat the same a third time;

then with fair water wash the remaining powder well: it will be of a brown colour inclining to red. In the observations we shall shew how the silver is to be separated from the *aqua fortis*.

OBSERVATIONS.

All the processes on silver already delivered, whether for extracting it from its ores, or for refining it, either by the cupel or by nitre, are applicable to gold also. And if silver be alloyed with gold before it undergo those several operations, it will still remain alloyed therewith after them, in the same manner, and in the same quantity; because both metals bear them equally. All therefore, that can be expected from those several assays, is the separation of every thing that is neither silver nor gold from these two metals. But in order to separate these two from each other, recourse must be had either to the process laid down under the head of gold, or to that here described, which is the most commodious, the most usual, and known by the names of *Quartation* and the *Parting Assay*.

Aqua fortis is the true solvent of silver, and is utterly incapable of dissolving the least atom of gold. If therefore a mass consisting of gold and silver be exposed to the action of *aqua fortis*, that acid will dissolve the silver contained in the compound without touching the gold, and the two metals will be separated from each other. This method of parting them is just the reverse of that described before under the head of gold, which is effected by the means of *Aqua regis*.

To the success of this separation, by means of *aqua fortis*, several conditions are essentially necessary. The first is that the gold and silver be in due proportion to each other; that is, there must be at least

least twice as much silver as gold in the metalline mass, otherwise the *aqua fortis* will not be able to dissolve it, for the reason formerly given. If therefore the mass contain too little silver, it must either be melted down again, and a proper quantity of silver added; or else, if the gold be in a sufficient proportion to the silver, they may be parted by means of *aqua regis*.

Secondly, it is necessary that the *aqua fortis* employed in this operation be absolutely pure, and free from any taint of the vitriolic or marine acid: or, if it be adulterated with the vitriolic acid, the silver will precipitate as fast as it dissolves, and so the precipitated silver will again mix with the gold. If the *aqua fortis* contain any of the marine acid, the silver will be precipitated in that case also; and this inconvenience will be attended with another, namely, that the menstruum, being partly an *aqua regis*, will dissolve some of the gold. You must therefore be very sure that your *aqua fortis* is pure, before you set about the operation. In order to discover its quality, you must try it by dissolving, in a small portion thereof, as much silver as it will take up: if the *aqua fortis* grow opaque and milky as it dissolves the silver, it is a sign it contains some foreign acid, from which it must be purified.

In order to effect this, let the portion of *aqua fortis* used for the above trial stand to settle: The white milky part will gradually fall to the bottom of the vessel. When it is all fallen, gently decant the clear liquor, and pour a few drops of this decanted solution of silver into the *aqua fortis* which you want to purify. It will instantly become milky. Let the white particles precipitate as before, and then add a few more drops of your solution of silver. If the *aqua fortis* still become milky, let it precipitate again, and repeat this till you find that a drop of your solution of silver, let fall into this *aqua fortis*, does not make it in the least tur-

bid. Then filter it through brown paper, and you will have an *aqua fortis* perfectly fit for the parting assay.

The white particles that appear and settle to the bottom, on dissolving silver in an *aqua fortis* adulterated with a mixture of some foreign acid, are no other than that very silver, which is no sooner dissolved by the nitrous acid than it deserts that solvent to unite with the vitriolic or marine acid, wherewith it has a greater affinity, and falls to the bottom with them. And this happens as long as there remains in the *aqua fortis* a single atom of either of those two acids.

When therefore your *aqua fortis* hath dissolved as much silver as it is capable of taking up, and when all the white particles formed during the dissolution are settled to the bottom, you may be assured that the portion which remains clear and limpid is a solution of silver in an exceeding pure *aqua fortis*. But if the solution of silver thus depurated be mixed with an *aqua fortis* adulterated with the vitriolic or marine acid, a like precipitation will immediately ensue, for the reasons above given, till the very last particle of the heterogeneous acid contained in the *aqua fortis* be precipitated.

Aqua fortis purified by this method contains no extraneous substance whatever, except a small portion of silver; so that it is very fit for the parting process. But if it be intended for other chymical purposes, it must be rectified in a glass retort with a moderate heat, in order to separate it from the small portion of silver it contains, which will remain at the bottom of the retort.

The third condition necessary to the success of this operation is that your *aqua fortis* be neither too aqueous, nor too highly concentrated. If too weak, it will not act upon the silver: and the consequence will be the same if it be too strong. Both these inconveniencies are easily remedied: for in the

the former case part of the superfluous phlegm may be drawn off by distillation; or a sufficient quantity of much stronger *aqua fortis* may be mixed with that which is too weak: and in the latter case, very pure rain water, or a weaker *aqua fortis*, may be mixed with that which is too strong.

You may satisfy yourself whether or no your *aqua fortis* hath the requisite degree of strength, by dissolving therein a thin plate consisting of one part gold, and two or three parts silver; which plate must be rolled up in form of a paper coffin. If, when all the silver contained in the plate is dissolved, the gold remains in the form of the coffin, it is a sign that your solvent has a due degree of strength. If, on the contrary, the gold be reduced to a powder, it is a proof that your *aqua fortis* is too strong, and ought to be weakened.

The gold remaining after the dissolution of the silver must be melted in a crucible with nitre and borax, as hath already been said under the process for parting gold and silver by means of *aqua regis*. As to the silver which remains dissolved in the *aqua fortis*, there are several ways to recover it.

The most usual is to precipitate it by the interposition of copper, which hath a greater affinity than silver with the nitrous acid*. For this purpose the solution is weakened by adding twice or thrice as much very pure rain water. The cucurbit containing the solution is set on a sand-bath gently heated, and very clean plates of copper put into it. The surfaces of these plates are soon covered with little white scales, which gradually fall to the bottom of the vessel, as they come to be collected in quantities. It is even proper to strike the cucurbit gently now and then, in order to shake the scales of silver from the copper-plates, and so make room for a new crop.

* See the Table of Affinities, Column IV.

The *aqua fortis* parts with the silver by degrees only, as it dissolves the copper; and therefore the liquor gradually acquires a blueish green colour as the precipitation advances. This precipitation of the silver is to be continued as long as any remains dissolved in the *aqua fortis*: you may be sure that your liquor contains no more silver, if the surface of a fresh plate of copper laid therein remain clean and free from ash-coloured or greyish particles; or if one drop of a solution of sea-salt let fall into it produce no white or milky cloud.

The precipitation being finished, the liquor is to be gently poured off from the precipitated silver, which must be rinsed in several waters, and even made to boil therewith, in order to free it wholly from the dissolved copper. The silver thus well washed must be thoroughly dried, mixed with a fourth of its weight of a flux compounded of equal parts of nitre and calcined borax, and then melted in a crucible. On this occasion care must be taken to raise the fire gently and gradually, till the silver be brought to fusion.

With what accuracy soever the precipitated silver be washed, in order to free it from the solution of copper, yet the silver will always be found alloyed with a small portion of the copper: but then this copper is easily destroyed by the nitre, with which the silver is afterwards melted; so that the latter metal remains perfectly pure after the operation.

Though the silver be not previously cupelled, but be alloyed with other metallic substances at the time it is thus dissolved, yet the dissolving, precipitating and fusing it with nitre would be sufficient to separate it accurately from them all, and refine it to a degree of purity equal to that obtained by the cupel.

The copper that remains dissolved in the *aqua fortis*, after the precipitation of the silver, may in like

ke manner be precipitated by iron, and, as it remains a small portion of silver, ought not to be neglected when these operations are performed on considerable quantities.

In the two next processes we shall shew two other methods of separating silver from *aqua fortis*.

PROCESS V.

To separate Silver from the Nitrous Acid by Distillation. Crystals of Silver. The Infernal Stone.

INTO a large, low, glass body put the solution of silver, from which you intend to separate the silver by distillation. To this body fit a tubulated head provided with its stopple. Set this alembic in a sand-bath, so that the body may be almost covered with sand: apply a receiver, and distil with a moderate heat, so that the drops may succeed each other at the distance of some seconds. If the receiver grow very hot, check the fire. When red vapours begin to appear, pour into the alembic, through the hole in its head, a fresh quantity of your solution of silver, first made very hot. Continue distilling in this manner, and repeating the addition of fresh liquor, till all your solution be put into the alembic. When you have no more fresh solution to put in, and when, the phlegm being all come over, red vapours begin again to appear, convey into the alembic half a dram or a dram of tallow, and distil to dryness; which being done, increase your fire, so as to make the vessel containing the sand-bath red-hot. In the alembic you will find a calx of silver, which must be melted

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melted in a crucible with some soap and calcined wine-lees.

OBSERVATIONS.

A low cucurbit is recommended for this operation, to the intent that the particles of the nitrous acid, which are ponderous, may the more easily be carried up and pass over into the receiver. For the same reason the cucurbit is directed to be almost wholly covered with sand; lest otherwise the acid vapours should be condensed about that part of the cucurbit, which, being out of the sand, would be much cooler than that which is encompassed therewith, and from thence should fall back again to the bottom; by which means the distillation would certainly be retarded, and the vessel probably be broken.

Notwithstanding these precautions the vessels are liable to break in such distillations; especially when they contain a great deal of liquor. With a view therefore to prevent this accident, we ordered that the whole quantity of the solution of silver to be distilled should not be put at once into the alembic. The little bit of tallow, added towards the end of the operation, is intended to hinder the metal from adhering closely to the vessel, as it would otherwise do, when all the moisture is dissipated.

The soap and fixed alkali mixed with the silver to flux it, after its separation from the *aqua fortis* in this way, serve to absorb such of the most fixed particles of the acid as may still remain united with the metal.

If the distillation be stopped when part of the phlegm is drawn off, and the liquor be then suffered to cool, many crystals will shoot therein, which are a neutral salt constituted of the nitrous acid and silver. If the distillation be carried further, and

and stopped when near its conclusion, the liquor being then suffered to cool will wholly coagulate into a blackish mass called the *Infernal Stone*.

This way of separating silver from its solvent is attended with the advantage of saving all the *aqua fortis*, which is excellent, and fit to be employed in other operations.

P R O C E S S VI.

To separate Silver from the Nitrous Acid by Precipitation. *Luna Cornea. Luna Cornea reduced.*

INTO your solution of silver pour about a fourth part in weight of spirit of salt, solution of sea-salt, or solution of sal ammoniac. The liquor will instantly become turbid and milky. Add twice or thrice its weight of fair water, and let it stand some hours to settle. It will deposite a white powder. Decant the clear liquor, and on the precipitate pour fresh *aqua fortis*, or spirit of salt, and warm the whole on a sand-bath with a gentle heat for some time. Pour off this second liquor, and boil your precipitate in pure water, shifting it several times, till the precipitate and the water be both quite insipid. Filter the whole, and dry the precipitate, which will be a *luna cornea*, and must be reduced in the following manner.

Smear the inside of a good crucible well with soap. Put your *luna cornea* into it; cover it with half its weight of salt of tartar, thoroughly dried and pulverised; press the whole hard down; pour thereon as much oil, or melted tallow, as the powder is capable of imbibing; set the crucible thus charged, and close covered, in a melting furnace, and

and, for the first quarter of an hour, make no more fire than is necessary to make the crucible moderately red: after that raise it so as to melt the silver and the salt, throwing into the crucible from time to time little bits of tallow. When it ceases to smoke, let the whole cool; or pour it into a hollow iron cone, warmed and tallowed.

OBSERVATIONS.

The process here delivered furnishes us with the means of procuring silver in a degree of purity which is not to be obtained by any other method of treating it whatever. That which is refined on the cupel always retains a small portion of copper, from which it cannot possibly be separated in that way: but if it be dissolved in *aqua fortis*, and precipitated thence in a *luna cornea* by the marine acid, the precipitate will be an absolutely pure silver, unalloyed with that small portion of copper which it retained on the cupel. The reason of this effect is, that the copper remains as perfectly dissolved in spirit of salt and in *aqua regia* as in *aqua fortis*: so that when the silver and the copper with which it is alloyed, are dissolved together in the nitrous acid, if the acid of sea-salt be mixed with the solution, part of this latter acid unites with the silver, and therewith forms a new compound, which not being soluble in the liquor, falls to the bottom. The other part of the acid mixing with the nitrous, forms an *aqua regis*, in which the copper remains dissolved, without separating from it.

Fresh acid is poured on the precipitated calx of silver, in order to complete the solution of the small portion of copper that may have escaped the action of the first solvent. It is indifferent whether the spirit of salt or the spirit of nitre be employed for this purpose, because they both dissolve copper alike.

like, and because silver precipitated by spirit of salt is not soluble in either.

After this it is necessary to wash the precipitate well with pure water, in order to free it entirely from the particles of *aqua fortis* adhering to the silver; because they may possibly contain something of copper, which would mix with the silver on melting, and taint its purity.

If this precipitate of silver be exposed to the fire, unmixed with any other substance, it melts as soon as it begins to be red; and if the fire be increased, part thereof will be dissipated in vapours, and the rest will make its way through the crucible. But being poured out as soon as melted, it coagulates into a cake of a purplish red colour, semi-transparent, ponderous, and in some degree pliable, especially if it be very thin. It bears some resemblance to horn, which hath occasioned it to be called, *luna cornea*.

As *luna cornea* is not soluble in water, recourse must be had to fusion, in order to reduce it, by separating from the silver those acids which give it the abovementioned properties. Fixed alkalis and fatty matters are very fit to produce that separation.

We directed that the inside of the crucible, in which the reduction is to be made, should be carefully smeared with soap, and that the *luna cornea* should be quite covered with a fixed alkali and fat, to the end that when the heat is strong enough to dissipate it in vapours, or to attenuate it so as to render it capable of penetrating the crucible, it may be forced to pass through matters qualified to absorb its acid, and reduce it.

Luna cornea may also be reduced by being melted with such metalline substances as have a greater affinity than silver with the acids wherewith it is impregnated. Of this kind are tin, lead, regulus of antimony: but the *luna cornea* rushes so impetuously

ously into conjunction with those metalline substances, that a vast many vapours arise, and carry off with them part of the silver: if therefore you chuse to effect the reduction by the interposition of such metalline substances, you must employ a retort instead of a crucible.

But this method is attended with another inconvenience; which is, that some part of those metalline substances may unite with the silver, and adulterate it; for which reason it is best to keep to the method first proposed.

P R O C E S S VII.

To dissolve Silver, and separate it from Gold, by Cementation.

MIX thoroughly together fine brick-dust four parts, vitriol calcined to redness one part, and sea-salt or nitre one part. Moisten this powder with a little water. With this cement cover the bottom of a crucible half an inch thick; on this first bed lay a thin plate of the mass of gold and silver you intend to cement, and which you must previously take care to beat into such thin plates. Cover this plate with a second layer of cement, of the same thickness as the former; on this second bed lay another plate of your metal; cover it in like manner with cement; and so proceed till the crucible be filled to within half an inch of its brim. Fill up the remaining space with cement, and close the crucible with a cover, luted with a paste made of Windsor-loam and water: set your crucible thus charged in a furnace, whose fire-place is deep enough to let it be entirely surrounded with coals, quite up to its mouth. Light some coals in

the furnace, taking care not to make the fire very brisk at first; encrease it by degrees, but only so far as to make the crucible moderately red; keep up the fire in this degree for eighteen or twenty hours: then let the fire go out; open the crucible when it is cold, and separate the cement from your plates of gold. Boil the gold repeatedly in fair water, till the water come off quite insipid.

OBSERVATIONS.

It cannot but seem strange that, after having so often declared the acid of sea-salt to be incapable of dissolving silver, we should direct either nitre or sea-salt indifferently to be employed in composing a cement, which is to produce an acid capable of eating out all the silver mixed with gold. It is easy to conceive how the nitrous acid extricated from its basis by means of the vitriolic acid may produce this effect: but if sea-salt instead of nitre be made an ingredient in the cement, its acid, though set at liberty in the same manner by the vitriolic acid, must at first sight appear unable to answer the end.

In order to remove this difficulty we must here observe, that there are two very essential differences between the marine acid collected in a liquor, as it is when distilled in the usual manner, and the same acid separated from its basis in a crucible, as it is in cementation.

The first of these two differences is, that the acid being reduced into vapours when it acts on the silver in cementation, its activity is thereby greatly increased: the second is, that in the crucible it sustains a vastly greater degree of heat than it can ever bear when it is in the form of a liquor. For, after it is once distilled and separated from its basis, it cannot sustain any extraordinary degree of heat without being volatilized and entirely dissipated:

whereas while it continues united with its basis it is much more fixed, and cannot be separated but by a very intense heat. Consequently, if it meet with any body to dissolve, at the very instant of its separation from its basis, while it is actuated by a much fiercer heat than can ever be applied to it on any other occasion, it must operate upon that body with so much the more efficacy : and thus it comes to pass that in cementation it has the power of dissolving silver, which it would be incapable of touching if it were not so circumstanced.

But herein gold differs from silver : for, whatever force the nitrous or the marine acid may exert, when extricated from their basis in the cementing crucible, this metal obstinately refuses to yield to either of those acids separately, and can never be dissolved by them, unless both be united together.

Our cementation therefore is actually a parting process in the dry way. The silver is dissolved, and the gold remains unaltered. Nay, as the action of the acids is much stronger when they are applied this way, than when they are used for dissolution in the moist way, the nitrous acid, which in the common parting process will not dissolve silver unless its weight be double that of the gold, is able in cementation to dissolve a very small quantity of silver diffused through a large quantity of gold.

It sometimes happens that after the operation the cement proves extremely hard, so that it is very troublesome to separate it entirely from the gold. In this case it must be softened by moistening it with hot water. This hardness which the cement acquires is occasioned by the fusion of the salts, which is the effect of too strong a heat. It was in order to prevent this, and that a due degree of heat might be applied, without the danger of melting the salts, that we directed the cement to be mixed

with

with a considerable quantity of earthy matter, incapable of fusion, such as brick-dust. A greater inconvenience still will ensue, if the fire be made so strong as to melt the gold: for then it will partly commix again with the other metalline substances dissolved by the cement, and consequently will not be purified.

The crucible is covered, and its cover luted on, to prevent the acid vapours from being too soon dissipated, and to force them to circulate the longer in the crucible. However, it is necessary that those vapours should find a vent at last, otherwise they would burst the vessel: and for this reason we directed the crucible to be luted only with Wind-or-loam, which does not grow very hard by the action of fire, and so is capable of yielding and giving passage to the vapours, when a certain quantity of them is collected in the crucible, and they begin to struggle for an escape on every side.

When the operation is finished, the silver dissolved by the acid of the cement is partly distributed through the cement, and partly in the gold itself, which is impregnated therewith. For this reason the gold must be washed several times in boiling water, till the water become absolutely insipid: or, if the gold be melted without this precaution, it will mix again with the silver: the cement also may be washed in the same manner to recover the silver it contains.

Though this cementation be, properly speaking, a purification of gold, yet we have placed it among the processes on silver, because it is the silver that is dissolved on this occasion, and because this is a particular way of dissolving that metal. Moreover, most of the processes hitherto delivered, either on gold or silver, are equally applicable to both these metals.

If the gold do not appear quite pure after the cementation, the process must be repeated.

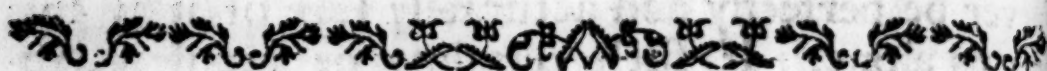
There are several ways to know the fineness of gold, the quantity of silver with which it is alloyed, and the proportion in which these two metals are mixed in a mass purified by the cupel.

One of the simplest is the trial by the touch-stone; which indeed is hardly any more than judging by the eye only, from the colour of the compound metal, what proportion of gold and silver it contains.

The touch-stone is a sort of black marble, whose surface ought to be half polished. If the metalline mass which you want to try be rubbed on this stone, it leaves thereon a thin coat of metal, the colour of which may be easily observed. Such as are accustomed to see and handle gold and silver can at once judge very nearly from this sample in what proportion the two metals are combined: but, for greater accuracy, those who are in the way of having frequent occasion for this trial are provided with a sufficient number of small bars or needles of which one is pure gold, another pure silver, and all the rest consist of these two metals mixed together in different proportions, varied by carats, or even by fractions of carats, if greater exactness be required.

The fineness of each needle being marked on it, that needle, whose colour seems to come nearest the colour of the metalline streak on the touch-stone, is rubbed on the stone by the side of the streak. This needle likewise leaves a mark; and if there appear to be no difference between the two metalline streaks, the metalline mass is judged to be of the same fineness as the needle thus compared with it. If the eye discovers a sensible difference, another needle is sought for whose colour may come nearer to that of the metal to be tried. But though a man be ever so well versed in judging

thus of the fineness of gold by the eye only, he can never be perfectly and accurately sure of it by this means alone. If such certainty be required, recourse must be had to the parting assay; and yet when you have gone through it, there always remains a small quantity of the metal, which should have been dissolved, and yet escaped the action of the solvent. For example, if you make use of *aqua regis*, the silver that remains after the operation still contains a little gold; and, if you make use of *aqua fortis*, the gold that remains after the operation still contains a little silver. And therefore if you resolve to carry the separation of these two metals still further by solvents, it will be necessary, after you have gone through one parting process, to perform a second the contrary way. For example, if you begin with *aqua fortis*, then, after it has dissolved all the silver in the metalline mass that it is capable of taking up, dissolve the remaining gold in *aqua regis*; by which means you will separate the small portion of silver left in it by the *aqua fortis*. The contrary is to be done if you make use of *aqua regis* first.



C H A P. III.

Of COPPER.

P R O C E S S I.

To separate Copper from its Ore.

BEAT your copper ore to a fine powder, having first freed it as accurately as possible, by washing and roasting, from all stony, earthy, sulphureous, and arsenical parts. Mix your ore thus pulverized with thrice its weight of the black flux; put the mixture into a crucible; cover it with common salt to the thickness of half an inch, and press the whole down with your finger. With all this the crucible must be but half full. Set it in a melting furnace; kindle the fire by degrees, and raise it insensibly till you hear the sea-salt crackle. When the decrepitation is over, make the crucible moderately red-hot for half a quarter of an hour. Then give a considerable degree of heat, exciting the fire with a pair of good perpetual bellows, so that the crucible may become very red-hot, and be perfectly ignited. Keep the fire up to this degree for about a quarter of an hour; then take out the crucible, and with a hammer strike a few blows on the floor whereon you set it. Break it when cold. If the operation hath been rightly and successfully performed, you will find at the bottom of the vessel a hard

ard regulus of a bright yellow colour, and semi-malleable; and over it a scoria of a yellowish brown colour, hard and shining, from which you may separate the regulus with a hammer.

OBSERVATIONS.

Copper in the ore is often blended with several other metallic substances, and with volatile minerals, such as sulphur and arsenic. Copper ores also frequently participate of the nature of the pyrites, containing a martial and an unmetallic earth, both of which are entirely refractory, and hinder the ore from melting. In this case you must add equal parts of a very fusible glass, a little borax, and four parts of the black flux, to facilitate the fusion. The black flux is moreover necessary to furnish the copper with the phlogiston it wants, or restore so much thereof as it may lose in melting. For the same reason, when any ore, but that of gold or silver, is to be smelted, it is a general rule to add some black flux, or other matter abounding with phlogiston.

The regulus produced by this operation is not malleable, because it is not pure copper, but a mixture of copper with all the other metallic substances that were in the ore; except such as were separated from it by roasting, of which it contains but little.

According to the nature of the metallic matters that remain combined with the copper after this fusion, the colour of the regulus is either like that of pure copper, or a little more whitish: it is also frequently blackish, which has procured it the name of *Black copper*. In this state, and even in general, it is usual enough to call this regulus by the name of *Black Copper*, when alloyed with other metallic substances that render it unmalleable, whatever its colour be.

Hence

Hence it appears that there may be several different sorts of black copper. Iron, lead, tin, bismuth, and the reguline part of antimony, are almost always combined with the ores of copper, in a multitude of different proportions; and all these substances, being reduced by the black flux in the operation, mix and precipitate with the copper. If the ore contain any gold or silver, as is pretty often the case, these two metals also are confounded with the rest in the precipitation, and become part of the black copper.

Pyritose, sulphureous, and arsenical copper ores may be fused, in order to get rid of the grosser heterogeneous parts, without previously roasting them: but in this case no alkaline flux must be mixed with the ore; because the alkali in combination with the sulphur would produce a liver of sulphur, and so dissolve the metalline part; by which means all would be confounded together, and no regulus, or very little, be precipitated. On this occasion, therefore, nothing must be added to promote the fusion, but some tender fusile glass, together with a small quantity of borax.

This first fusion may also be performed amidst the coals, by casting the ore upon them in the furnace, without using a crucible; and then an earthen vessel, thoroughly heated, or even made red-hot, must be placed under the grate of the fire place, to receive the metal as it runs from the ore.

The regulus obtained by this means is much more impure and brittle than black copper, because it contains, moreover, a large quantity of sulphur and arsenic; as these volatile substances have no time to evaporate during the short space requisite to melt the ore, and as they cannot be carried off by the action of the fire after the ore is once melted, whatever time be allowed for that purpose. However, some part thereof is dissipated; and the

iron which is in pyritose ores, having a much greater affinity than copper, and indeed than any other metallic substance, with sulphur and arsenic, absorbs another part thereof, and separates it from the regulus.

This regulus, it is plain, still contains all the same parts that were in the ore, but in different proportions; there being more copper, combined with less sulphur, arsenic, and unmetallic earth, which have been either dissipated or turned to slag. Therefore if you would make it like black copper, you must pound it, roast it over and over, to free it from its sulphur and arsenic, and then melt it with the black flux.

If this regulus contain much iron, it will be advisable to melt it once or twice more, before all the sulphur and arsenic are separated from it by roasting; for as the iron, by uniting with these volatile substances, separates them from the copper, with which they have not so great an affinity; so the sulphur and arsenic, by uniting with the iron, help in their turn to separate it from the copper.

P R O C E S S II.

To purify black Copper, and render it malleable.

Break into small bits the black copper you intend to purify; mix therewith a third part in weight of granulated lead, and put the whole into a cupel set under the muffle in a cupelling furnace, and previously heated quite red. As soon as the metals are in the cupel raise the fire considerably, making

making use, if it be needful, of a pair of perpetual bellows, to melt the copper speedily. When it is thoroughly melted, lower the fire a little, and continue it just high enough to keep the metalline mass in perfect fusion. The melted matter will then boil, and throw up some *scoriae*, which will be absorbed by the cupel.

When most of the lead is consumed, raise the fire again till the face of the copper become bright and shining, thereby shewing that all its alloy is separated. As soon as your copper comes to this state, cover it with charcoal-dust conveyed into the cupel with an iron-ladle : then take the cupel out of the furnace and let it cool.

OBSERVATIONS.

Of all the metals, next to gold and silver, copper bears fusion the longest without losing its phlogiston ; and on this property is founded the process here delivered for purifying it.

It is necessary the copper should melt as soon as it is in the cupel, because its nature is to calcine much more easily and much sooner, when it is only red-hot, than when it is in fusion. For this reason the fire is to be considerably raised, immediately on putting the copper under the muffle that it may melt as soon as possible. Yet too violent a degree of fire must not be applied to it : for when it is exposed to such a degree of heat only as is but just necessary to keep it in fusion, it is then in the most favourable condition for losing as little as may be of its phlogiston ; and if the heat be stronger, a greater quantity thereof will be calcined. As soon therefore as it flows it is proper to weaken the fire, and reduce it to the degree just requisite to keep up the fusion.

The lead added on this occasion is intended to facilitate and expedite the scorification of the metal.

substances combined with the copper. So that the event is here nearly the same as when gold or silver is refined on the cupel. The only difference between this refining of copper, and that of the perfect metals, is that the latter, as hath been shewn, absolutely resist the force of fire and the action of lead, without suffering the least alteration; whereas a good deal of copper is calcined and destroyed, when it is purified in this manner on the cupel. Indeed it would be wholly destroyed, if a greater quantity of lead were added, or if it were left too long in the furnace. It is with a view to save as much of it as possible that we order it to be covered with charcoal-dust as soon as the scorification is finished.

The lead serves moreover to free the copper expeditiously from the iron with which it may be alloyed. Iron and lead are incapable of contracting any union together: so that as fast as the lead unites with the copper, it separates the iron, and excludes it out of the mixture. For the same reason if iron were combined in a large proportion with copper, it would prevent the lead from entering into the composition. Now, as it is necessary to give the more heat, and to keep the copper to be incorporated with lead the longer in fusion, as that copper is alloyed with a greater proportion of iron, some black flux must be added on this occasion, to prevent the copper and the lead from being calcined before their association can be effected.

Copper purified in the manner here directed is beautiful and malleable. It is now alloyed with no other metalline substance but gold or silver, if there were any in the mixed mass. If you desire to extract this gold or silver, recourse must be had to the operation of the cupel. The process here given for purifying copper is not used in large works, because it would be much too chargeable. In order

der to purify their black copper, and render it malleable, the smelters content themselves with roasting it, and melting it repeatedly, that the metallic substances which are not so fixed as copper may be dissipated by sublimation, and the rest scorified by fusion.

PROCESS III.

To deprive Copper of its Phlogiston by Calcination.

PUT your copper in filings into a test, and set it under the muffle of a cupelling furnace; light the fire, and keep up such a degree of heat as may make the whole quite red, but not enough to melt the copper. The surface of the copper will gradually lose its metalline splendour, and put on the appearance of a reddish earth. From time to time stir the filings with a little rod of copper or iron, and leave your metal exposed to the same degree of fire till it be entirely calcined.

OBSERVATIONS.

In our observations on the preceding process we took notice that copper, in fusion, calcines more slowly, and less easily, than when it is exposed to a degree of fire barely sufficient to keep it red-hot, without melting it; and therefore, the design here being to calcine it, we have directed that degree of heat only to be applied.

The cupelling furnace is the fittest for this operation, because the muffle is capable of receiving such a flat vessel as ought to be used on this occasion.

ion, and communicating to it a great deal of heat; while, at the same time, it prevents the falling in of any coals, which, by furnishing the copper with fresh phlogiston, would greatly prejudice and obstruct the operation.

As copper calcines with great difficulty, this operation is extremely tedious: nay, though copper hath stood thus exposed to the fire for several days and nights, and seems perfectly calcined, yet it frequently happens that, when you try afterwards to melt it, some of it resumes the form of copper: a proof that all the copper had not lost its phlogiston. Copper is much more expeditiously deprived of its phlogiston by calcining it in a crucible with nitre.

The calx of copper perfectly calcined is with great difficulty brought to fusion: yet, in the focus of a large burning glass, it melts and turns to a reddish and almost opaque glass.

By the process here delivered, you may likewise calcine all other metalline substances, which do not melt till they be thoroughly red hot. As to those which melt before they grow red, they are easily enough calcined, even while they are in fusion.

PROCESS IV.

To resuscitate the Calx of Copper, and reduce it to Copper, by restoring its Phlogiston.

MIX the calx of copper with thrice as much of the black flux; put the mixture into a good crucible, so as to fill two thirds thereof, and over it put a layer of sea-salt a finger thick. Cover the crucible, and set it in a melting furnace; heat it gradually, and keep it moderately red till the decrepitation of the sea-salt be over. Then raise the fire considerably by means of a good pair of perpetual bellows: satisfy yourself that the matter is in perfect fusion, by dipping into the crucible an iron wire; continue the fire in this degree for half a quarter of an hour. When the crucible is cold, you will find at its bottom a button of very fine copper, which will easily separate from the saline scoria at top.

OBSERVATIONS.

What hath been said before on the smelting of copper ores may be applied to this process, as being the very same. The observations there added should therefore be consulted on this occasion.

P R O

P R O C E S S V.

To dissolve Copper in the Mineral Acids.

ON a sand-bath, in a very gentle heat, set a matrafs containing some copper filings; pour on them twice their weight of oil of vitriol. That acid will presently attack the copper. Vapours will rise, and issue out of the neck of the matrafs. A vast number of bubbles will ascend from the surface of the metal to the top of the liquor, and the liquor will acquire a beautiful blue colour. When the copper is dissolved, put in a little and a little more, till you perceive the acid no longer acts upon it. Then decant the liquor, and let it stand quiet in a cool place. In a short time great numbers of beautiful blue crystals will shoot in it. These crystals are called *vitriol of copper*, or *blue vitriol*. They dissolve easily in water.

O B S E R V A T I O N S.

The vitriolic acid perfectly dissolves copper: which is also soluble in all the acids, and even in any other menstruums.

This acid may be separated from the copper which it hath dissolved by distillation only: but the operation requires a fire of the utmost violence. The copper remaining after it must be fused with the black flux, to make it appear in its natural form; not only because it still retains a portion of the acid, but also because it hath lost part of its logiston by being dissolved therein. The black flux is very well adapted both to absorb the acid

that remains united with the copper, and to restore the phlogiston which the metal hath lost.

The most usual method of separating copper from the vitriolic acid is by presenting to that acid a metal with which it hath a greater affinity than with copper. Iron being so qualified is consequently very fit to bring about this separation. When therefore plates of iron well cleaned are laid in a solution of blue vitriol, the acid soon begins to act upon them, and, by degrees, as it dissolves them, deposits on their surfaces a quantity of copper in proportion to the quantity of iron it takes up. The copper thus precipitated hath the appearance of small leaves or scales, exceeding thin, and of a beautiful copper colour. Care must be taken to shake the iron-plates now and then, to make the scales of copper fall off, which will otherwise cover them entirely, hinder the vitriolic acid from attacking the iron, and so put a stop to the precipitation of the remaining copper.

When these scales of copper cease to settle on the clean iron plates, you may be sure all the copper that was in the liquor is precipitated, and that this liquor, which was a solution of copper before the precipitation, is a solution of iron after it. So that here two operations are performed at one and the same time; to wit, the precipitation of the copper, and the dissolution of the iron.

The copper thus precipitated requires only to be separated from the liquor by filtration, and melted with a little black flux, to become a very fine malleable copper.

The copper may also be precipitated out of a solution of blue vitriol by the interposition of a fixed alkali. This precipitate is of a greenish blue colour, and requires a much greater quantity of the black flux to reduce it.

Copper dissolves in the nitrous acid, in the marine acid. and in *aqua regis*; from all of which

may be separated by the same methods as are here ordered with regard to the vitriolic acid.



CHAP. IV.

Of IRON.

PROCESS I.

To separate Iron from its Ore.

POUND into a coarse powder the martial stones or earths out of which you design to extract the iron: roast this powder in a test under the muffle for some minutes, and let your fire be brisk, then let it cool, beat it very fine, and roast it a second time, keeping it under the muffle till it emit no more smell.

Then mix with this powder a flux composed of three parts of nitre fixed with tartar, one part of file glass, and half a part of borax and charcoal-dust. The dose of this reducing flux must be twice the weight of the ore.

Put this mixture into a good crucible; cover it with about half a finger thick of sea-salt; over the crucible put its cover, and lute it on with Windforam made into a paste with water. Having thus prepared your crucible, set it in a melting furnace, which you must fill up with charcoal. Light the fire, and let it kindle by gentle degrees, till the crucible becomes red-hot. When the decrepitation of the sea-salt is over, raise your fire to the highest by the blast of a pair of perpetual bellows, or rather several. Keep up this intense degree of heat for

for three quarters of an hour, or an whole hour, taking care that during all this time the furnace be kept constantly filling up with fresh coals as the former consume. Then take your crucible out of the furnace; strike the pavement on which you set it several times with a hammer, and let it stand to cool: break it, and you will find therein a regulus of iron covered with slag.

OBSERVATIONS.

Iron ore, like all others, requires roasting, to separate from it, as much as possible, the volatile minerals, sulphur and arsenic, which being mixed with the iron would render it unmalleable. Indeed it is so much the more necessary to roast these ores, as iron is, of all metallic substances, that which has the greatest affinity with those volatile minerals; on which account no metallic substance whatever is capable of separating it from them by fusion and precipitation.

Fixed alkalis, it is true, have a greater affinity than iron with sulphur; but then the composition which a fixed alkali forms with sulphur is capable of dissolving all metals. Consequently, if you do not dissipate the sulphur by roasting, but attempt to separate it from the iron by melting the ore with a fixed alkali, the liver of sulphur formed in the operation will dissolve the martial part; so that after the fusion you will find little or no regulus.

All iron ores in general are refractory, and less fusible than any other; for which reason a much greater proportion of flux, and a much more violent degree of fire, is required to smelt them. One principal cause why these ores are so refractory is the property which iron itself has of being extremely difficult to fuse, and of resisting the action of the fire so much the more as it is purer, and further removed from its mineral state. Among all the metallic

metallic substances it is the only one that is less fusible when combined with that portion of phlogiston which gives it the metalline form, than when it is deprived thereof, and in the form of a calx.

In smelting-houses iron ore is fused amidst charcoal, the phlogiston of which combines with the martial earth. and gives it the metalline form. The iron thus melted runs down to the bottom of the furnace, from whence it is let out into large moulds, in which it takes the shape of oblong blocks, called *Pigs* of iron. This iron is still very impure, and quite unmalleable. Its want of ductility after the first melting arises partly from the presence, that, notwithstanding the previous roasting which the ore underwent, there still remains, after its first fusion, a considerable quantity of sulphur and arsenic combined with the metal.

A certain quantity of quick-lime, or of stones that will burn to lime, is frequently mixed with iron ore on putting it into the smelting furnace. The lime being an absorbent earth, very apt to unite with sulphur and arsenic, is of use to separate those minerals from the iron.

It is also of use to mix some such matters with the ore, when the stones or earths which naturally accompany it are very fusible; for, as the iron is of difficult fusion, it may happen that the earthy matters mixed with the iron shall melt as easily as the metal, or perhaps more easily. In such a case there is no separation of the earthy from the metalline part, both of which melt and precipitate together promiscuously: now quick-lime, being extremely refractory, serves on this occasion to check the melting of those matters which are too fusible.

Yet quick-lime, notwithstanding its refractory quality, may sometimes be of use as a flux for iron. This is the case when the ore happens to be combined

combined with substances, which, being united with lime, render it fusible : such are all arsenical matters, and even some earthy matters, which being combined with quick-lime make a fusible compound.

When the ore of an iron mine is found difficult to reduce, it is usually neglected even though it be rich ; because iron being very common, people chuse to work those mines only whose ores are smelted with the most ease, and require the least consumption of wood.

Yet refractory ores are not to be altogether rejected, when another iron ore of a different quality is found near them. For it often happens that two several iron ores, which being worked separately are very difficult to manage, and yield at last but bad metal, become very tractable, and yield excellent iron, when smelted together : and accordingly such mixtures are often made at iron works.

The iron obtained from ores by the first fusion may be divided into two sorts. The one, when cold, resists the hammer, doth not easily break, and is in some measure extensible on the anvil ; but if struck with a hammer when red-hot flies into many pieces : this sort of iron hath always a mixture of sulphur in it. The other sort, on the contrary, is brittle when cold, but somewhat ductile when red-hot. This iron is not sulphurated, is naturally of a good quality, and its brittleness arises from its metalline parts not being sufficiently compacted together.

Iron abounds so much, and is so universally diffused through the earth, that it is difficult to find a body in which there is none at all : and this hath led several chymists, even men of great fame, into the error of thinking that they had transmuted into iron several sorts of earths in which they suspected no iron, by combining them with an inflammable matter.

matter; whereas, in fact, all they did was to give the metalline form to a true martial earth, which happened to be mixed with other earths.

P R O C E S S II.

To render Pig-iron and brittle Iron malleable.

NT O an earthen vessel widening upwards put some charcoal-dust, and thereon lay the pig-iron which you propose to render ductile; cover it over with a quantity of charcoal; excite the fire gently with a pair, or more, of perpetual bellows till the iron melt. If it do not readily flow and form a great deal of slag on its surface, add some sand, such as a very fusible sand.

When the matter is in fusion keep stirring it from time to time, that all the parts thereof may be equally acted on by the air and the fire. On the surface of the melted iron *scoriae* will be formed, which must be taken off as they appear. At the same time you will see a great many sparkles darted from the surface of the metal, which will form a sort of fiery shower. By degrees, as the iron grows purer, the number of these sparkles diminishes, though they never vanish intirely. When a few sparkles appear, remove the coals which cover the iron, and let the slag run out of the vessel: thereupon the metal will grow solid in a moment. Take it out while it is still red-hot, and give it a few strokes with a hammer, to try if it be ductile. If it be not yet malleable, repeat the operation a second time, in the same manner as before. Lastly, when it is thus sufficiently purified by the fire, work

work it for a long time on the anvil, extending it in different ways, and making it red-hot as often as there is occasion. Iron thus brought to the necessary degree of ductility, so as to yield to the hammer, and suffer itself to be extended every way, either hot or cold, without breaking to bits, or even cracking in the least, is very good and very pure. If it cannot be brought to this degree by the method here prescribed, it is a proof that the ore from which this iron was extracted ought to be mixed with other ores; but it frequently requires a great number of trials to obtain an exact knowledge of the quality and proportion of those other ores with which it is to be mixed.

OBSERVATIONS.

The brittleness and shortness of pig-iron arise from the heterogeneous parts which it contains and which could not be separated from it by the first fusion. These extraneous matters are usually sulphur, arsenic, and unmetallic earth, and also ferruginous earth; but such as could not be combined with the phlogiston as it ought to be, in order to have the properties of a metal, and must therefore be considered as heterogeneous, with respect to the other well conditioned martial particles.

The pig-iron by undergoing repeated fusions, is freed from those heterogeneous matters; those which are volatile, such as sulphur and arsenic being dissipated, and the unmetallic matters being scorified. As to the ferruginous earth, which does not at first acquire the metalline form, it becomes true iron at last; because among the coals with which it is encompassed, it meets with a sufficient quantity of phlogiston to reduce it to metal. Charcoal is also necessary on this occasion, that it may

contin

continually furnish phlogiston to the iron, which would otherways be converted into a calx.

Hammering the red-hot iron, after each fusion, serves to force out from amongst the martial parts such earthy matters as may happen to remain there, and so to bring into closer contact the metalline parts which were separated before by the interposition of these heterogeneous matters.

P R O C E S S III.

To convert Iron into Steel.

TAKE small bars of the best iron; that is, of such as is malleable both hot and cold; set them on their ends in a cylindrical earthen vessel, whose depth is equal to the length of the bars, and in such a manner that they may be an inch distant from each other, and from the sides of the crucible. Fill the vessel with a cement compound of two parts of charcoal, one part of bones burnt in a close vessel till they become very black, and one half part of the ashes of green wood; having first pulverized and thoroughly mixed the whole together. Take care to lift up the Iron bars a little, to the end that the cement may cover the bottom of the vessel, and so that there be about the depth of half an inch thereof under every bar: cover the crucible and lute on the cover.

Set the crucible thus prepared in a furnace, so contrived that the crucible may be surrounded with coals from top to bottom: for eight or ten hours keep up such a degree of fire that the vessel may be moderately red; after this take it out of the furnace; plunge your little iron bars into cold water,

water, and you will find them converted into steel.

OBSERVATIONS.

The principal difference between iron and steel consists in this, that the latter is combined with a greater quantity of phlogiston than the former.

It appears by this experiment, that, to make iron unite with an inflammable matter, it is not necessary it should be in fusion; it is sufficient that it be so red-hot as to be opened and softened by the fire.

Every kind of charcoal is fit to be an ingredient in the composition of the cement employed to make steel, provided it contain no vitriolic acid. However, it hath been observed that animal coals produce a speedier effect than others: for which reason it is proper to mix something of that kind with charcoal-dust, as above directed.

The following signs shew that the operation hath succeeded, and that the iron is changed into good steel.

This metal being quenched in cold water, as proposed above, acquires such an extraordinary degree of hardness, that it will by no means yield to any impression of the file or hammer, and will sooner break in pieces than stretch upon the anvil. And here it is proper to observe, that the hardness of steel varies with the manner in which it is quenched. The general rule is, that the hotter the steel is when quenched, and the colder the water is in which you quench it, the harder it becomes. It may be deprived of the temper thus acquired, by making it red-hot, and letting it cool slowly; for it is thereby softened, rendered malleable, and the file will bite upon it. For this reason the artificers who work in steel begin with untempering it, that they may with more ease shape it into the tool they intend

intend to make. They afterwards new-temper the tool when finished, and by this second temper the steel recovers the same degree of hardness it had acquired by the first temper.

The colour of steel is not so white as that of iron, but darker, and the grains, facets, or fibres, which appear on breaking it, are finer than those observed in iron.

If the bars of iron thus cemented in order to convert them into steel be too thick, or not kept long enough in cementation, they will not be turned into steel throughout their whole thickness: their surfaces only will be steel to a certain depth, and the centre will be mere iron; because the phlogiston will not have thoroughly penetrated them. On breaking a bar of this sort, the difference in colour and grain between the steel and the iron is very visible.

It is easy to deprive steel of the superabundant quantity of phlogiston which constitutes it steel, and thereby reduce it to iron. For this purpose it need only be kept red-hot some time, observing that no matter approach it all the while, that is capable of refunding to it the phlogiston which the fire carries off. The same end is still sooner obtained by cementing it with meagre hungry matters, capable of absorbing the phlogiston; such as bones calcined to whiteness, and cretaceous earths.

Steel may also be made by fusion; or pig-iron may be converted into steel. For this purpose the same method must be employed as was above directed for reducing pig-iron into malleable iron; with this difference, that, as steel requires more phlogiston than is necessary to iron, all the means must be made use of that are capable of introducing into the iron a great deal of phlogiston; such as melting but a small quantity of iron at a time, and keeping it constantly encompassed with abundance

dance of charcoal ; reiterating the fusions ; taking care that the blast of the bellows directed along the surface of the metal do not remove the coals that cover it, &c. And here it must be observed, that there are some sorts of pig-iron which it is very difficult to convert into steel by this method, and that there are others which succeed very readily, and with scarce any trouble at all. The ores which yield the last-mentioned sort of pig-iron are called *steel ores*. Steel made by this means must be tempered in the same manner as that made by cementation *.

P R O C E S S IV.

The Calcination of Iron. Sundry Saffrons of Mars.

TAKE filings of iron, in what quantity you please ; put them into a broad unglazed earthen vessel ; set it under the muffle of a cupelling furnace ; make it red-hot ; stir the filings frequently ; and keep up the same degree of fire till the iron be wholly turned into a red powder.

O B S E R V A T I O N S.

Iron easily loses its phlogiston by the action of fire. The calx that remains after its calcination is exceeding red ; which makes this be thought the natural colour of the earth of that metal. It hath accordingly been observed, that all the earths and

* Mr. Réaumur hath obliged the publick with a treatise on the means of converting iron into steel, in which he hath exhausted the subject. Such as desire the amplest and most useful instructions on that part of metallurgy, would do well to consult his work.

stones, which either are naturally red, or acquire that colour by calcination, are ferruginous.

The yellowish red colour which every calx of iron hath, in whatever manner it be prepared, hath procured the name of *crocus* or *saffron* to every preparation of this kind. That made in the manner above directed is called in medicine *crocus martis astringens*.

The rust produced on the surface of iron is a sort of calx of iron made by the way of dissolution. The moisture of the air acts upon the metal, dissolves it, and robs it of some of its phlogiston. This rust is called in medicine *crocus martis aperiens*; because it is thought that the saline parts, by means whereof the humidity dissolves the iron, remain united with the metal after its dissolution, and give it an aperitive virtue. The apothecaries prepare this sort of saffron of mars by exposing iron filings to the dew, till they be turned entirely to rust; which is then called *saffron of mars by dew*.

Another saffron of mars is also prepared in a much shorter manner, by mixing filings of iron with pulverized sulphur, and moistening the mixture, which after some time ferments and grows hot. It is then set on the fire; the sulphur burns away, and the mass is kept stirring till it become a red matter. This saffron is nothing but iron dissolved by the acid of sulphur, which is known to be of the same nature with that of vitriol; and consequently this saffron of mars is no way different from vitriol calcined to redness.

PROCESS V.

Iron dissolved by the mineral Acids.

PUT any mineral acid whatever into a matrafs with some water ; set the matrafs on a sand-bath gently heated ; drop into the vessel some filings of iron : the phenomena which usually accompany metalline dissolutions will immediately appear. Add more filings, till you observe the acid hath lost all sensible action upon them ; then remove your matrafs from the sand-bath ; you will find in it a solution of iron.

OBSERVATIONS.

Iron is very easily dissolved by all the acids. If you make use of the vitriolic acid, care must be taken to weaken it with water, in case it be concentrated ; because the dissolution will succeed the better. The vapours that rise on this occasion are inflammable ; and if a lighted paper be held to the mouth of the matrafs, especially after keeping it stopt for some time and shaking the whole gently, the sulphureous vapours take fire with such rapidity as to produce a considerable explosion ; which is sometimes strong enough to burst the vessel into a thousand pieces. This solution hath a green colour, and is in fact a fluid green vitriol, which wants nothing but rest to make it shoot into crystals.

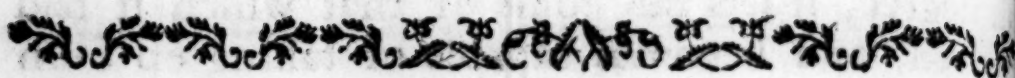
If you make use of the nitrous acid, you must cease adding more filings when the liquor, after standing still some moments, becomes turbid ; for when

When this acid is impregnated with iron to a certain degree, it lets fall some of that which it had dissolved, and becomes capable of taking up fresh iron. Thus by constantly adding new supplies of iron, this acid may be made to dissolve a much greater quantity thereof than is necessary to saturate it entirely. This solution is of a ruflet colour, and doth not crystallize.

If the weather be not extremely cold, and the acids have a proper degree of strength, the sand-bath is unnecessary, as the dissolution will succeed very well without it.

Iron dissolved by acids may be separated therefrom, like all other metallic substances in the same circumstances, either by the action of fire, which carries off the acid and leaves the martial earth, or by the interposition of substances which have a greater affinity than metallic substances have with acids; that is, by absorbent earths and alkaline salts. By whatever means you separate iron from an acid solvent, it constantly appears, after the separation, in the form of a yellowish red powder; because it is then deprived of most of the phlogiston to which it owed its metallic form: whence it is reasonable to think, that this is the proper colour of martial earth.

All these precipitates of iron are true saffrons of Mars, which, as well as those prepared by calcination, are so much the further removed from the nature of a metal, the more they are deprived of their phlogiston. Thence it comes that they are more or less soluble by acids, and more or less attracted by the magnet: as no ferruginous earth, perfectly deprived of all inflammable matter, is not all attracted by the magnet, or soluble by acids.



C H A P. V.

Of T I N.

P R O C E S S I.

To extract Tin from its Ore.

Break your tin ore into a coarse powder, and by washing carefully separate from it all the heterogeneous matters, and ores of a different kind that may be mixed therewith. Then dry it, and roast it in a strong degree of fire, till no more arsenical vapour rise from it. When the ore is roasted, reduce it to a fine powder, and mix it thoroughly with twice its weight of the black flux well dried, a fourth part of its weight of clean iron filings, together with as much borax and pitch: put the mixture into a crucible; over all put sea-salt to the thickness of four fingers, and cover the crucible close.

Set the crucible thus prepared in a melting furnace: apply at first a moderate and flow degree of fire, till the flame of the pitch, which will escape through the joint of the cover, disappear entirely. Then suddenly raise your fire, and urge it with rapidity to the degree necessary for melting the whole mixture. As soon as the whole is in fusion take the crucible out of the furnace, and separate the regulus from the scoria.

OBSERVATIONS.

All tin ores contain a considerable quantity of arsenic, and no sulphur at all, or at most very little.

Hence it comes that, though tin be the lightest of all metals, its ore is nevertheless much heavier than any other; arsenic being much heavier than sulphur, of which the ores of every other metal always contain a pretty large proportion. This ore is moreover very hard, and is not brought to a fine powder with so much ease as the rest.

These properties of tin ore furnish us with the means of separating it easily by lotion, not only from earthy and stony parts, but even from the other ores which may be mixed with it. And this is of the greater advantage on two accounts, viz. because tin cannot endure, without the destruction of a great part thereof, the degree of fire necessary to scorify the refractory matters which accompany it; and again because this metal unites so easily with iron and copper, the ores of which are pretty commonly blended with tin ore, that, after the reduction, it would be found adulterated with a mixture of these two metals, if they were not separated from it before the fusion.

But sometimes the iron ore confounded with that of tin is very heavy, and is not easily pulverized; so that when it comes to pass that it cannot be separated from it by washing only. In that case the magnet must be employed to separate it, after the ore has been roasted.

Roasting is moreover necessary for tin ore, in order to dissipate the arsenic which volatilizes, calcine, or destroys one part of the tin, and reduces the rest to a short, brittle substance, like a semimetal. The ore is known to be sufficiently roasted when no more fumes rise from it; when it has lost the

the smell of garlick ; and when it does not whiten a clean plate of iron held over it.

Tin being one of those metals which are most easily calcined, it is necessary in reducing its ore to employ such matters as may furnish it with phlogiston. In order to defend it from the contact of the air, which always accelerates the calcination of metallic substances, the mixture is to be covered with sea-salt ; and the addition of pitch helps to increase the quantity of phlogiston.

PROCESS II.

The Calcination of Tin.

INto an unglazed earthen dish put the quantity of tin you intend to calcine, melt it, and keep stirring it from time to time. Its surface will be covered with a greyish white powder : continue the calcination till all your tin be converted into such powder, which is the *calx of tin*.

OBSERVATIONS.

Though the calcination of metalline substances is promoted by exposing them, in powder, or filings, to the action of fire, and by ordering it that they may not melt, because they present a much smaller surface when melted than when unmelted yet we have not directed this precaution to be used in calcining tin. The reason is, this metal is so fusible that it cannot endure the degree of fire requisite to destroy its phlogiston without melting and of course, though tin calcines easily, the operation

tion is nevertheless tedious, because the melted metal presents but a small surface to be acted on by the fire and the air. This inconvenience may be partly remedied, and the operation greatly expedited, by dividing the quantity of tin to be calcined into several small parcels, and exposing them to the fire in separate vessels, so that they may not re-unite when melted, and form one single mass.

Leaf tin cast on nitre in actual fusion causes it to deflagrate and fulminate; and from this mixture there rises a white vapour, which is converted into flowers when it meets with any obstacle to impede its flying off entirely.

Mr. Geoffroy, who went through a course of experiments on tin, an account whereof may be seen in the Memoirs of the Academy of Sciences, found that from the colour of the calx of that metal a judgement may be formed of its degree of purity, and nearly of the quantity and quality of the metallic substances with which it is alloyed. The experiments tried on this subject by that eminent Chymist are very curious.

He performed the calcination in a crucible, which he heated to a cherry red, and kept up the same degree of fire from the beginning to the end of the operation. The calx which formed upon the metal, in that degree of heat, appeared like small white scales, a little reddish on the under side. He pushed it to one side as it formed, to the end that it might not cover the surface of the metal, which, like all others, requires the contact of the air to turn it into a calx.

While he was making these calcinations, he had an opportunity of observing a curious fact, of which no body before him had ever taken notice; probably because no body had ever calcined tin by the same method. The fact is, that during the calcination of the tin, whether you break the pellicle which forms on the surface of
* the

“ the metal while in red-hot fusion, or whether
“ you let it remain without touching it, you per-
“ ceive in several places a small swell of a certain
“ matter, which bursts and makes its way through
“ the pellicle. This matter puffs up, grows red
“ at the same instant takes fire, and darts out a
“ small whitish flame, as vivid and as brilliant as
“ that of zinc, when urged by a fire strong enough
“ to sublime it into flowers. The vividness of this
“ flame may be further compared to that of several
“ small grains of phosphorus of urine fired and
“ gently dropped on boiling water. From this
“ bright flame a white vapour exhales ; after which
“ the swelled mass partly crumbles down, and turns
“ to a light white powder, sometimes spotted with
“ red, according to the force of the fire. After
“ this momentary ignition, there arise stronger
“ more numerous, or more frequent heavings of
“ matter, out of which issues a good deal of white
“ fume, that may be intercepted by a cover of
“ tin-plate or copper fitted to the crucible, and
“ appears to be the flowers of tin, which in some
“ measure corrode those metals. Hence Mr. Geoffroy
“ conjectures, with a great deal of probability,
“ that their sublimation is promoted by a por-
“ tion of arsenic. When the crust formed by this
“ calx comes to be too thick, or in too great
“ quantity, to be pushed on one side, so as to leave
“ part of the metal uncovered, Mr. Geoffroy puts
“ out the fire, because no more calx would be
“ formed ; the communication of the external air
“ with the tin in fusion being absolutely necessary
“ thereto, as hath been already said. In this op-
“ ration it is to be observed that, if the fire be too
“ flow, neither the inflammation of the sulphur-
“ ous particles, nor the white fumes that rise, will
“ be so distinctly perceived, as when the fire is
“ the degree requisite to keep the crucible just of
“ cherry-red heat.

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“ Mr. Geoffroy having taken off this first calx began the calcination anew. In this second heat the buddings or heavings were more considerable, and shot up in the form of cauli-flowers; but were still composed of little scales. The thoroughly calcined portion of this vegetation was likewise white and red; and the inferior surfaces of some little bits thereof were wholly red. When these calcinations are continued, sulphureous vapours rise seemingly of another kind than those which appeared in the beginning; for all the calx made by the first heat was perfectly white; whereas in the second it begins to be spotted here and there with a tinge of black. Mr. Geoffroy was obliged to go through a course of twelve several calcinations before he could convert two ounces of tin into a calx. He had the opportunity, during these several calcinations, to observe that after the fourth, and sometimes after the third, the red spots of the calx decrease, and the black increase; that the germinations cease; that the crust of the calx remains flat; that in the twelfth fire the tin yields no more of this scaly crust; that towards the end the undulations of the fused metal appear no longer; and that the small remainder of calx is mixed with several very minute grains of metal, which seem much harder than tin. Mr. Geoffroy could not collect a sufficient quantity thereof to cupel them, and satisfy himself whether or no they were silver.”

Though tin, and all the imperfect metals in general, seem converted to a calx, and lose the metalline form, by one single calcination, and that a slight one; yet they are not wholly deprived of their logiston: for if the calx of tin, for instance, prepared according to the process above delivered, be cast upon nitre in fusion, it will make that salt flagrate very perceptibly; a convincing proof that

that it still contains much inflammable matter. It therefore a calx be required absolutely free from phlogiston, this first calx must be re-calcined by a more violent fire, and the calcination continued till all the phlogiston be dissipated.

“ Mr. Geoffroy, being desirous of having his
 “ calx of tin very pure and perfectly calcined, ex-
 “ posed once more to the action of fire the twelve
 “ portions of calx obtained by his former calcina-
 “ tions. But, as it would have been too tedious
 “ to re-calcine them all separately, he made four
 “ parcels of the whole, each consisting of three
 “ taken according to the order in which they were
 “ first calcined ; and gave to each a fire sufficient-
 “ ly strong, and long enough continued, to cal-
 “ cine them as thoroughly as was possible. After
 “ this second calcination he found them all of a
 “ most beautiful white, except the first parcel : as
 “ that consisted of the portions obtained by the
 “ three first heats, in all of which there were scales
 “ tinged with red, it still retained a stain of carna-
 “ tion, though hardly perceptible. Agreeably to
 “ the general rule, the two ounces of tin gained in
 “ weight by being thus calcined ; and the increase
 “ was two drams and fifty-seven grains.

“ Mr. Geoffroy observes that no tin, but what
 “ is absolutely pure, will yield a perfectly white
 “ calx. He calcined in this manner several other
 “ parcels of tin that were impure and variously
 “ alloyed ; each of which produced a calx differ-
 “ ently coloured, according to the nature and
 “ quantity of its alloy : whence he justly concludes
 “ that calcination is a very good method of trying
 “ the fineness of tin, or its degree of purity.” The
 particulars of Mr. Geoffroy's experiments on this
 subject, which are very curious, may be seen in the
 Memoirs of the Academy for 1738.

It is proper to take notice that a man should be
 very cautious how he exposes himself to the vapours

of tin, because they are dangerous; this metal being very justly suspected by chymists of containing something arsenical.

PROCESS VII.

The dissolution of Tin by Acids. The Smoking liquor of Libavius.

PUT into a glass vessel what quantity you please of fine tin cut into little bits. Pour on it thrice as much *aqua regis*, compounded of two parts *aqua fortis* weakened with an equal quantity of very pure water, and one part spirit of salt. An ebullition will arise, and the tin will be very rapidly dissolved; especially if the quantities of metal and of *aqua regis* be considerable.

OBSERVATIONS.

Tin is soluble by all the acids; but *aqua regis* dissolves it best of any. Yet in this dissolution it comes to pass that part of the dissolved tin precipitates of its own accord to the bottom of the vessel, in the form of a white powder. This solution of tin is very fit for preparing the purple-coloured precipitate of gold. For this purpose the solution of tin must be let fall, drop by drop, into a solution of gold. Spirit of nitre dissolves tin nearly as *aqua regis* does; but it occasions a greater quantity of calx.

If two or three parts of oil of vitriol be poured on one part of tin, and if the vessel in which the mixture is made be exposed to such a degree of

heat as to evaporate all the moisture, there will remain a tenacious matter sticking to the sides of the vessel. If water be poured on this matter, and it be then exposed a second time to the fire, it will dissolve entirely, excepting a small portion of a glutinous substance, which also may be dissolved in fresh oil of vitriol.

The acid of sea-salt may be combined with tin by the following process. Mix perfectly, by trituration in a marble mortar, an amalgam of two ounces of fine tin, and two ounces and a half of quicksilver, with as much corrosive sublimate. As soon as the mixture is completed, put it into a glass retort, and distill with the same precautions as we directed to be used in preparing concentrated and smoking acids. There will first come over into the receiver some drops of a limpid liquor, which will be soon followed by an elastic spirit that will issue out with impetuosity. At last some flowers, and a saline tenacious matter, will rise into the neck of the retort. Then stop your distillation, and pour into a glass bottle the liquor you will find in the receiver. This liquor continually exhales a considerable quantity of dense, white fumes, as long as it is allowed to have a free communication with the air.

The product of this distillation is a combination of the acid of sea-salt with tin. As the affinity of tin with this acid is greater than that of mercury, the acid contained in the corrosive sublimate quits the mercury, wherewith it was united, to join the tin; which it volatilizes so as to make it rise with itself in a liquid form. We make use of the amalgam of tin with quicksilver, because we are thereby enabled to mix the corrosive sublimate perfectly therewith, as the success of the operation requires it should be.

In this experiment the tin is volatilized, and the acid of sea-salt, which is exceedingly concentrated,

ies off incessantly in the form of white vapours. This compound is known in chymistry by the name of the *Smoking liver of Libavius*; a name derived from its quality; and from its inventor. Tin dissolved by acids is easily separated from them by alkalis. It always precipitates in the form of a white alk.



C H A P. VI.

Of LEAD.

P R O C E S S I.

To extract Lead from its Ore.

HAVING roasted your lead ore reduce it to a fine powder; mix it with twice its weight of the black flux, and one fourth of its weight of clean iron filings and borax; put the whole into a crucible capable of containing at least thrice as much; over all put sea-salt four fingers thick; cover the crucible; lute the juncture; dry the whole with a gentle heat, and set it in a melting furnace.

Make the crucible moderately red: you will hear the sea-salt decrepitate, and after the decrepitation small hissing in the crucible. Keep up the same degree of fire till that be over.

Then throw in as many coals as are necessary to complete the operation entirely, and raise the fire suddenly, so as to bring the whole mixture into perfect

fect fusion. Keep up this degree of fire for a quarter of an hour, which is time sufficient for the precipitation of the regulus.

When the operation is finished, which may be known by the quietness of the matter in the crucible, and by a bright vivid flame that will rise from it, take the crucible out of the furnace, and separate the regulus from the scoria.

OBSERVATIONS.

All lead ore contains a good deal of sulphur, which must be first separated from it by roasting: and as this kind of ore is apt to fly when first exposed to the fire, it is proper to keep it covered till it be thoroughly heated. Another precaution to be used, in roasting this ore, is not to give it too great a heat, but to keep the vessel which contains it just moderately red; because it easily turns clammy, which occasions it to stick to the vessel.

The iron that is added, and mixed with the flux, absorbs the sulphur which may happen to remain, even after roasting: it helps also to separate from the lead some portions of semi-metal, especially of antimony, which are frequently mixed with this ore.

There is no fear lest the iron mix with the lead in fusion, and adulterate it: for these two metals are incapable of contracting any union together, when each has its metalline form.

Nor is there any reason to apprehend lest the iron should, by its refractory quality, obstruct the fusion of the mixture; for though this metal be not fusible when alone, yet, by the union it contracts with the matters it is designed to absorb, it becomes so to such a degree as in some measure to perform, on this occasion, the office of a flux.

The government of the fire is a point of great consequence in this operation. It is necessary to apply

apply but a moderate degree of heat at first: for, when the metallic earth of the lead, combining with the phlogiston, acquires the metalline form, it swells up in such an extraordinary manner, that there is great danger lest the matter should overflow, and run all out of the containing vessel. With a view therefore to avoid this inconvenience, we direct a very large crucible to be used. This heaving of the lead, at the instant of its reduction, is attended with a noise like the whistling of wind.

Notwithstanding all the precautions that can be used to prevent the reduction from taking place too hastily, and so occasioning the effusion of the matter, it often happens that, on raising the fire in order to bring the mixture into fusion, the hissing suddenly begins again, and is very loud. In that case all the apertures of the furnace must immediately be shut close, in order to choak and suffocate the fire: for, if this be neglected, the matter in the crucible will swell up, make its way through the luting of the juncture, nay, push up the cover, and run over. This accident is to be apprehended during the first five or six minutes after you raise the fire in order to melt the mixture. This effusion of the matter is accompanied with a full flame, a thick, grey and yellow smoke, and a noise like that of some boiling liquor. When you observe these several phenomena you may be sure the matter is run out of the crucible, either in the manner above described, or by making its way through some cracks in the vessel, and consequently that the operation is spoiled.

Moreover, this event infallibly follows whenever a bit of coal happens to fall into the crucible; and this is one reason why it is necessary to cover it.

You may be certain that the operation hath succeeded if the scoria be smooth when cold, and have not

not in part escaped through the lute; if the lead be not dispersed in globules through the whole mass of the matter contained in the crucible, but is, on the contrary, collected at the bottom, in the form of a solid regulus, not very shining, but of a blueish cast, and ductile. Moreover the scoria ought, in the present case, to be hard and black, and should not appear full of holes like a sieve, except only in that part which was contiguous to the salt.

Here it is proper to observe that the sea-salt doth not mix with the scoria, but floats upon it. After the operation it is black; which colour it gets, no doubt, from the charred parts of the flux. The absence of these signs shews the operation to have miscarried,

When the ore to be smelted is pyritose and refractory, it may be roasted at first with a much stronger degree of fire than is used for ores that are fusible; because the martial earth, and the un-metallic earth, which are always mixed in pyritose matters, hinder it from growing readily soft in the fire. Besides, such an ore requires a greater quantity of the black flux and of borax to be mixed with it, and a higher degree of fire to fuse it.

It is generally needless to mix iron filings with this sort of ore; because the martial earth, with which pyritose matters are always accompanied, is reduced during the operation by the help of the black flux, which for that purpose is mixed with it in a large proportion, and furnishes a quantity of iron sufficient to absorb the heterogeneous minerals mixed with the lead.

Yet, if it should be observed that the pyrites which accompany the lead ore are arsenical, then as such pyrites contain but a small quantity of ferruginous earth, iron filings must be added; which are, on this occasion, so much the more necessary for absorbing the arsenic, as this mineral remains

in part confounded with the ore, is reduced to a regulus during the operation, unites with the lead, and destroys a great deal of it by procuring its vivification.

The lead obtained from such pyritose ores is commonly not very pure; it is blackish and scarce ductile; qualities communicated to it by a small mixture of copper in the pyrites, which always contain more or less thereof. We shall presently shew the method of separating lead from copper.

Lead ore may also be reduced by melting it amongst coals. For that purpose first kindle a fire in the furnace in which you intend to melt your ore; then put a layer of your ore immediately upon the lighted coals, and cover it with another layer of coals.

Though the melting furnace used for this operation be capable of giving a considerable heat, yet it is necessary further to increase the force of the fire by the means of a good pair of perpetual bellows, which will produce an effect like that of a forge. When the ore melts, the earth of the lead unites with the phlogiston of the coals, and so is reduced to metal, which runs through the coals, and falls into an earthen vessel placed at the bottom of the furnace to receive it. Care must be taken to keep this vessel well filled with charcoal-dust, to the end that the lead may be in no danger of calcination while it continues there; the charcoal-dust constantly furnishing it with phlogiston to preserve its metalline form.

The earthy and stony matters that accompany the ore are scorified by this fusion, just as they are by the other which is performed in a close vessel. With regard to the sulphur and arsenic, they are supposed to have been first accurately separated from the ore by roasting. This is the method commonly employed for smelting lead ore at the works.

PRO-

PROCESS II.

To separate Lead from Copper.

WITH luting earth and charcoal-dust make a flat vessel, widening upwards, and large enough to contain your metalline mass. Set it shelving downwards from the back towards the fore part; and in the fore part, at the bottom, make a little gutter communicating with another vessel of the same nature, placed near the former and a little lower. Let the mouth of the gutter within side the upper vessel be narrowed, by means of a small iron plate fixed across it, while the loam is yet soft; so as to leave a very small aperture, in the lower part of this canal, sufficient to discharge the lead as it melts. Dry the whole by placing lighted coals around it.

When this apparatus is dry, put your mixed mass of copper and lead into the upper vessel: both in that, and in the other vessel, light a very gentle fire of wood or charcoal, so as not to exceed the degree of heat necessary to melt lead. In such a degree of heat the lead contained in the mixed mass will melt, and you will see it run out of the upper vessel into the lower; at the bottom of which it will unite into a regulus. When in this degree of heat no more lead flows, increase the fire a little, so as to make the vessel moderately red.

When no more will run, collect the lead contained in the lower vessel. Melt it over again in an iron ladle, with a degree of fire sufficient to make the ladle red; throw into it a little tallow or pitch, and while it burns keep stirring the metal, in order

to reduce any part of it that may be calcined. Remove the pellicle or thin crust which will form on the surface; squeeze out all the lead it contains, and then put it to the mass of copper left in the upper vessel. Check the fire, and in the same manner take off a second skin that will form on the surface of the lead. Lastly, when the metal is ready to fix, take off the skin that will then appear on it. The lead remaining after this will be very pure, and free from all alloy of copper.

With regard to the copper itself, you will find it in the upper vessel covered with a thin coat of lead: and if the lead mixed with it was in the proportion of a fourth or a fifth part only, and the fire applied was gentle and slow, it will retain nearly the same form after the operation that the mixed mass had before.

OBSERVATIONS.

Lead frequently remains mixed with copper after the reduction of its ore, especially if the ore was vitriolose. Though copper be a much more beautiful and more ductile metal than lead, yet the latter being alloyed with the former is rendered eager and brittle. This bad quality is easily discovered by the eye on breaking it: for the surface of the broken part appears all granulated; whereas when it is pure it is more evenly, and resembles a congeries of solid angles. If the lead be alloyed with a considerable quantity of copper, its colour hath a yellowish cast.

Considering the bad qualities which copper communicates to lead, it is necessary to separate these two metals from each other. The method above described is the simplest and the best. It is founded on two properties belonging to lead: the first is that of being much more fusible than copper; so that it will melt and run in a degree of heat that is not

not capable of making the copper even red-hot, which yet is very far from being able to melt it: the second is, that lead, though it hath an affinity with copper, and unites very perfectly therewith, yet is not able to dissolve it without a greater heat than the degree barely necessary to fuse lead. Hence it comes that lead may be melted in a copper vessel, provided no greater degree of heat be applied than that purpose requires. But when the lead becomes so hot as to be red, fume and boil, it instantly begins to dissolve the copper. For this reason, it is essential to the success of our operation that a moderate degree of heat only be applied, and no greater than is requisite to keep the lead in fusion.

Charcoal-dust is made an ingredient in the composition of the vessels used on this occasion, in order to prevent the calcination of the lead.

The iron plate, with which the entrance of the gutter within the upper vessel is narrowed, serves to prevent the larger pieces of copper, which the lead may carry along with it, from passing thro' it stops them, and allows the lead to run off alone.

But as these parcels of copper may entirely choak the passage, care must be taken, when any happen to be stoppt, to remove them from the entrance of the gutter, and push them back into the middle of the vessel. It is also necessary to observe, whether or no the lead fixes any where in the passage; and, if it does, the heat of that part must be increased, in order to melt it and make it run off.

Notwithstanding all the precautions that can be taken, to hinder the melted lead from carrying off any copper with it, it is impossible to prevent this inconvenience entirely: and therefore the lead is melted over again, in order to separate the small portions

portion of copper with which it is still adulterated.

As copper is much lighter than lead, if these two metals happen to be so blended together that the copper, without being in fusion and dissolved by the lead, is only interposed between the parts of the melted lead, so as to swim therein, it is then precisely in the case of a solid body plunged into a fluid heavier than itself, and must rise to the surface, like wood thrown into water. It is proper to burn some inflammable matter on this melted lead, in order to reduce such parts thereof as are constantly calcining on its surface while it is in fusion; or without this precaution they would be taken off together with the copper.

The copper remaining after this separation is, as we took notice before, still mixed with a little lead. If you desire to separate it entirely therefrom, you must put it into a cupel, and expose it under the muffle to such a degree of fire as may convert all the lead into litharge. This cannot be so done but that some of the copper also will be scorified by the heat of the fire, and by the action of the lead: but as there is very great difference between the facility and readiness with which these two metals calcine, the portion of copper that is calcined, while the whole lead is turning into litharge, is scarce worth considering.

The lead, though carefully separated from the copper by the process here delivered, is not yet absolutely pure: sometimes it is alloyed with gold, and almost always contains some silver. If you would free the lead as much as possible from any mixture of these two metals, you must convert it into glass, separate the remaining bead, and afterwards reduce this glass of lead. But, as these two perfect metals are of no prejudice to the lead, it is not usual to separate them from it, unless they

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be in a sufficient proportion to defray the charge, and produce some profit besides.

When we examine by the cupel the just proportion of gold and silver that an ore or a mixed metalline mass will yield, we make a previous assay of the lead to be employed in the operation, and afterwards, in our estimate, deduct a proper allowance for the quantity of fine metal due to the lead made use of.

PROCESS III.

The Calcination of Lead.

TAKE what quantity of lead you please; melt it in one or more unglazed earthen pans: a dark grey powder will be found on its surface. Keep stirring the metal incessantly till it be wholly converted into such a powder, which is the *calx* of lead.

OBSERVATIONS.

As lead is a very fusible metal, and in that respect greatly resembles tin, most of the observations we made on the calcination of tin may be applied here.

In the calcination of all metals, and particularly in this of lead, there appears a singular phenomenon, which is not easily accounted for. It is this: though these matters lose a great deal of their substance, either by the dissipation of their phlogiston or because some of the metal, perhaps, exhales in vapours, yet, when the calcination is over, their calx

calxes are found to be encreased in weight, and this increase is very considerable. An hundred pounds of lead, for example, converted into minium, which is nothing but a calx of lead brought to a red colour by continuing the calcination, are found to gain ten pounds weight; so that for an hundred pounds of lead we have one hundred and ten pounds of minium: a prodigious and almost incredible augmentation, if it be considered that, far from adding any thing to the lead, we have on the contrary dissipated part of it.

To account for this phenomenon natural philosophers and chymists have invented several ingenious hypotheses, but none of them entirely satisfactory. As we have no established theory to proceed upon, we shall not undertake to explain this extraordinary fact.

P R O C E S S I V.

To prepare Glafs of Lead.

TAKE two parts of litharge, and one part of pure crySTALLINE sand; mingle them together as exactly as possible, adding a little nitre and sea-salt: put this mixture into a crucible of the most solid and most compact earth. Shut the crucible with a cover that may perfectly close it.

Set the crucible thus prepared in a melting furnace; fill the furnace with coals; light the fire gradually, so that the whole may be slowly heated: then raise the fire so as to make the crucible very red, and bring the matter it contains into fusion; keep it thus melted for a quarter of an hour.

Then take the crucible out of the furnace, and break it: in the bottom thereof you will most commonly find a small button of lead, and over it a transparent glass, of a yellow colour nearly resembling that of amber. Separate this glass from the little button of metal, and from the saline matters which you will find above it.

OBSERVATIONS.

Pure lead, being exposed to a strong fire without any additament, turns to litharge; which is a scaly sort of substance, more or less yellowish, shining, and soft to the touch. This is the first advance to the vitrification of lead. The large refineries of gold and silver by the means of lead furnish a great quantity of this material. It is sometimes whitish, and is then called *litharge of silver*; sometimes yellow, and then bears the name of *litharge of gold*. The difference of its colour depends on the degree of fire it hath undergone, and on the metalline substances vitrified with it.

Litharge alone is very fusible, and being exposed to the fire is easily converted into glass: but this glass of lead, made without additament, is so active, so penetrating, and so apt to swell, that it can scarcely be made use of when pure. We are obliged in some sort to clog it, by uniting it with some vitrifiable matter that is not so subtil, such as sand; and it is for this reason, not to render the mixture more fusible, that we have directed the addition of one third part of sand to two thirds of litharge.

The nitre and sea salt, prescribed as ingredients in the mixture, are designed to procure an equal fusion of the whole. For, as the sand is lighter and less fusible than the litharge, it will partly rise towards the upper part of the crucible when that matter first begins to flow; in consequence where-

of the contents of the upper part will be much more difficult to melt, and form a glass much more compact than that below: but the nitre and sea-salt possessing the upper part of the crucible, because they are still lighter than the sand, and being in their own nature very efficacious fluxes, on account of their great fusibility, they quickly bring about the fusion of those particles of sand, which, having escaped the action of the litharge, may have risen unvitriified to its surface.

The most difficult thing to procure, and yet the most necessary to the success of this operation, is a crucible of earth so firm and compact as not to be penetrated by the glass of lead, which corrodes and makes its way through every thing.

The precaution of chusing a crucible, that shall contain a good deal more than the matter to be vitrified, is a necessary one, because litharge and glass of lead are very apt to swell.

The rule to keep the crucible close shut is also indispensibly necessary, to prevent any bit of charcoal, or other inflammable matter, from falling into it: for when this happens it occasions a reduction of the lead, which is always attended with a sort of effervescence, and such a considerable heaving, that commonly most of the mixture runs over the crucible. For the same reason it is very proper, before you expose the mixture to the fire, to examine whether or no it contains any matter capable of furnishing a phlogiston during the operation; and if it does, to remove that matter with great care.

The little button of lead, found at the bottom of the crucible after the operation, comes from a small portion of lead that is commonly left in litharge, unless you prepare it carefully yourself, and do not take it from the fire till you are sure of having destroyed all the lead. Besides, this small portion of lead can be of no prejudice to the operation,

ration, because it cannot communicate its phlogiston to the rest of the matter.

The revivifying of litharge, of the calx, and of the glass of lead, may be obtained by the same processes as the reduction of its ore.

PROCESS V.

Lead dissolved by the Nitrous Acid.

PUT into a matrafs some *aqua fortis* precipitated, like that used to dissolve silver; weaken it by mixing therewith an equal quantity of common water; set the matrafs in a hot sand-bath; throw into it, little by little, small bits of lead, till you see that no more will dissolve. *Aqua fortis* thus lowered will dissolve about a fourth of its weight of lead.

There is gradually formed upon the lead, as it dissolves, first a grey powder, and afterwards a white crust, which at last hinder the solvent from acting on the remaining part of the metal; and therefore the liquor should be made to boil, and the vessel should be shaken to remove those impediments, by which means all the lead will be dissolved.

OBSERVATIONS.

Lead very much resembles silver, with respect to the phenomena which attend its dissolution in acids. For example, the nitrous acid must be very pure and uncontaminated with the vitriolic or marine acid, to qualify it for keeping the lead in solution

for

for, if it be mixed with either the one or the other of these acids, the lead will precipitate in the form of a white powder as fast as it dissolves; which is just the case with silver.

If the vitriolic acid be mixed with the nitrous, the precipitate will be a combination of the vitriolic acid with lead; that is, a neutral metallic salt, or vitriol of lead. If the acid of sea-salt be mixed therewith, the precipitate will be a *plumbum corneum*; that is, a metallic salt resembling the *luna cornea*.

When all the lead is dissolved as above described, the liquor appears milky. If it be kept warm over the fire till little crystals begin to appear on its surface, and afterwards left to stand quiet, in a certain time there will be found at the bottom a greyish powder, which being tried on gold is mercurial enough to whiten it. Little globules of quick-silver are even discernible in it.

We owe this observation, together with this manner of proving the existence of mercury in lead, and of procuring it from thence, to M. Groffe, who hath given an account of his process in the Memoirs of the Academy of Sciences, from whence we have copied the description of the operation in hand.

The solution being quickly poured off by inclination from the grey mercurial precipitate is still milky, and deposits another white sediment. When this second precipitate falls, the liquor becomes clear and limpid, and is then of a fine yellow colour, like a solution of gold. On this gold-coloured solution, and on the two precipitates above-mentioned, M. Groffe made several observations, the chief of which we shall here insert.

The yellow liquor affects the tongue at first with a taste of sweetness; but afterwards vellicates it very smartly, and leaves on it a strong sensation of acrimony, which continues for a long time.

Alkalis

Alkalis precipitate the lead suspended in this liquor, just as they do all other metals dissolved by acids; and this precipitate of lead is white.

Sea-salt, or spirit of salt, separates the lead from its solvent, and precipitates it, as we observed before, into a *plumbum corneum*: but this precipitate differs from the *luna cornea*, as being very soluble in water; whereas the *luna cornea* will not dissolve in it at all: or at least dissolves therein with great difficulty, and in a very small quantity. This *plumbum corneum* dissolved in water is again precipitated by the vitriolic acid. M. Groffe observes that this forms an exception to the eighth column of Mr. Geoffroy's table of affinities; in which the acid of sea-salt is marked as having a greater affinity than any other acid with metallic substances.

Our solution of lead is also precipitated in a white powder by several neutral salts; such as vitriolated tartar, alum, and common vitriol. It is by the means of double affinities that these neutral salts effect this precipitation.

Even pure water alone is capable of precipitating the lead of our solution, by weakening the acid, and thereby disabling it from keeping the metal suspended.

Lastly, as all the solutions of metals in acids are nothing but neutral metallic salts in a fluid form, so if the solution of lead be evaporated over the fire, it will shoot into very beautiful crystals, about the bigness of hemp-seed, shaped like regular pyramids having square bases. These crystals are yellowish, and have a sweet saccharine taste: but what is most singular in them is, that, as they consist of the nitrous acid combined with lead, which manifestly contains a great deal of phlogiston, they constitute a nitrous metallic salt, which has the property of deflagrating in a crucible, without the addition of any other inflammable matter. It is extremely hard to dissolve this salt in water.

The grey mercurial precipitate which whitens old, and in which little globules of running mercury are perceivable, is far from being pure mercury. This metallic substance makes but a small part thereof: for it is an assemblage; 1. of little crystals of the same nature with those afforded by the evaporated solution; 2. of a portion of the white matter, or powder, which renders the solution milky; 3. of a grey powder which M. Grosse considers as the only mercurial part; 4. and lastly, of little particles of lead that have escaped the action of the solvent; especially if a little more lead than the acid is capable of dissolving were added with a view to saturate it entirely, as in the present process.

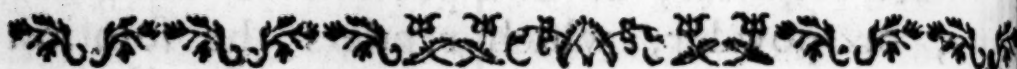
By means of motion and heat the small parcels of Mercury may be amalgamated with the lead.

That mercury should be found intire and in globules in the spirit of nitre, which very easily dissolves that metallic substance, will not be surprizing to those who reflect that, in the present case, the acid is saturated with lead, with which it has a greater affinity than with mercury; as appears by Geoffroy's Table of Affinities, where, in the column that hath the nitrous acid at top, lead is placed above mercury. Agreeably to this, if lead be presented to a solution of mercury in spirit of nitre, the lead will be dissolved, and as the dissolution thereof advances the mercury will precipitate.

Hence it appears that, in order to find any mercury in the spontaneous precipitate of lead dissolved in the nitrous acid, it is necessary that the acid be entirely saturated with lead; or else that portion of the acid which remains unsaturated will dissolve the mercury.

With regard to the white powder that renders the solution milky, and afterwards precipitates, it is nothing but a portion of the lead, which, not being intimately

intimately united with the acid, fails in part of its own accord. It is a sort of calx of lead, which being exposed to the fire becomes partly glass, and partly lead, because it still retains some of its phlogiston.



CHAP. VII.

Of MERCURY.

PROCESS I.

To extract Mercury from its Ore, or to revivify it from Cinabar.

PULVERIZE the cinabar from which you would extract the mercury; with this powder mix an equal part of clean iron filings; put the mixture into a retort of glass or iron, leaving at least one third part thereof empty. Set the retort thus prepared in a sand-bath, so that its body may be quite buried in the sand, and its neck declining considerably downwards: fit on a receiver half filled with water, and let the nose of the retort enter about half an inch into the water.

Heat the vessels so as to make the retort moderately red. The mercury will rise in vapour which will condense into little drops, and fall into the water in the receiver. When you see that nothing more comes over with this degree of heat increase it, in order to raise what mercury may

will be left. When all the mercury is thus brought over, take off the receiver, pour out the water contained in it, and collect the mercury.

OBSERVATIONS.

Mercury is never mineralized in the bowels of the earth by any thing but sulphur; with which it forms a compound of a brownish red colour, known by the name of *Cinabar*.

Sometimes it is only mixed with earthy and stony matters that contain no sulphur; but as this metallic substance is never destitute of its phlogiston, then has its metalline form and properties. When it is found in this condition, nothing is more easy than to separate it from those heterogeneous matters. For that purpose no more is requisite than to distill the whole with a fire strong enough to raise the mercury in vapours. This mineral is volatile; the earthy and stony matters are fixed; and a certain degree of heat will effect a complete separation of what is volatile from what is fixed.

This is not the case when mercury is combined with sulphur: for this latter mineral is volatile as well as mercury; and the compound resulting from the union of them both is also volatile: so that if *Cinabar* were exposed to the fire in close vessels, as must be to save the mercury, it would be sublimed in substance, without being decomposed at all.

In order therefore to separate these two substances from each other, we must have recourse to the interposition of some third, which hath a greater affinity with one of them than the other hath, and no affinity with that other.

Iron hath all the conditions requisite for this purpose; seeing it hath, as may be seen in the table, a much greater affinity with sulphur than mercury hath, and is incapable of contracting any union with mercury.

Iron,

Iron, however, is not the only substance that may be employed on this occasion : Fixed alkalis, absorbent earths, copper, lead, silver, regulus of antimony, have all, as well as iron, a greater affinity than mercury with sulphur. Nay, several of these substances, namely, the saline and earthy alkalis as well a regulus of antimony, cannot contract any union with mercury ; the rest, to wit, copper, lead and silver, are indeed incapable of amalgamation with mercury ; but then the union which these metals contract with the sulphur prevents it ; and even though they should unite with this metallic substance, the degree of heat to which the whole mixture is exposed would soon carry up the mercury, and separate it with ease from those fixed substances.

In this distillation the same cautions must be observed as in all others : that is, the vessels must be slowly heated, especially if a glass retort be used the fire must be raised by degrees, and a much stronger one applied at last than at first. This operation particularly requires a very strong degree of fire, when there is but a small quantity of mercury left.

After the operation there remains in the retort a compound of iron and sulphur, which may easily be converted into a *crocus*, by calcining it and burning away the sulphur.

If a fixed alkali be employed, a liver of sulphur will be found in the retort after the distillation.

If the cinabar, from which you extract the mercury be good, you will generally obtain several eighths of its weight in quick-silver.

In the present operation it is not necessary to lute on the receiver, because the water, in which the nose of the retort is plunged, is sufficient to fix the mercurial vapours. In case the cinabar, from which you intend to separate the mercury, be mixed with a great quantity of heterogeneous, but

d, matters, such as earths, stones, &c. it may be separated from them by subliming it with a proper degree of heat, because it is volatile.

The vapours of mercury are prejudicial, and may excite a salivation, tremors, and palsies; they should therefore be always avoided by such as work in this mineral.

The oldest and richest mine of mercury is that of Almaden in Spain. It is a singular property of that mine that, though the mercury found in it is combined with sulphur, and in the form of cinabar, yet no aditament is required to procure the separation of these two; the earthy and stony matter, with which the particles of the ore are incorporated, being itself an excellent absorbent of sulphur.

In the quick-silver works carried on at this mine they make no use of retorts. They place lumps of the ore on an iron-grate, which stands immediately over the furnace. The furnaces which serve for this operation are closed at the top by a sort of dome, behind which stands the shaft of a chimney that communicates with the fire-place, and gives vent to the smoke. These furnaces have in their fore-side sixteen apertures, to each of which is luted an aludel in a horizontal position, communicating with a long row of other aludels placed likewise in a horizontal direction: which aludels so connected together form one long pipe or canal, the farther end whereof opens into a chamber destined to receive and condense all the mercurial vapours. These rows of aludels are supported from end to end by a terrass, which runs from the body of the building, wherein the furnaces are erected, to that where the chambers are built that perform the office of receivers.

This is a very ingenious contrivance, and saves much labour, expence, and trouble, that would be unavoidable if retorts were employed.

That part of the furnace which contains the lumps of ore, serves for the body of the retort; the row of aludels for its neck: and the little chambers in which these canals terminate are actual receivers. The terrafs of communication, which reaches from the one building to the other, is formed of two inclined planes, the lower edges of which, meeting in the middle of the terrafs, rise from thence insensibly; the one quite to the building where the furnaces are, and the other to that which forms the recipient chambers. By this means, when any mercury escapes through the joints of the aludels, it naturally runs down along these inclined planes, and so is collected in the middle of the terrafs, where the inferior sides of the planes meeting together form a sort of canal, out of which it is easily taken up.

The celebrated M. de Jussieu having viewed the whole himself, in a journey he made to this mine, furnished us with this description of the work.

PROCESS II.

To give Mercury, by the action of Fire, the appearance of a Metalline Calx.

PUT mercury into several little glass matraffes with long and narrow necks. Stop the matraffes with a little paper, to prevent any dirt from falling into them. Set them all in one sand-bath so that they may be surrounded with sand as high as two thirds of their length. Apply the strongest degree of heat that mercury can bear without subliming: continue this heat without interruption till all the mercury be turned to a red powder, The operation lasts about three months

OBSERVATIONS.

Mercury treated according to the process here delivered hath all the appearance of a metalline calx, but it hath no more: For, if it be exposed to a pretty strong degree of fire, it sublimes, and is wholly reduced to running mercury, without the addition of any other inflammable matter; which proves that, during its long calcination, it lost none of its phlogiston.

The volatile nature of mercury, which permits it not to bear a heat of any strength without subliming, prevents our examining all the effects that fire is capable of producing on it. Yet there is reason to believe that, as this metallic substance resembles the perfect metals in its weight, its splendour, and a brilliancy which resists all the impressions of the air without alteration, it would like them be unchangeable by the greatest force of fire, if it were fixed enough to bear it.

In order to give mercury the form of a metalline calx, it must necessarily be exposed for about three months together, to the utmost heat it can bear without subliming, as is above directed. Boerhaave kept it digesting in a less heat for fifteen years successively, both in open and in close vessels, without observing it to suffer the least change; except that there was formed upon its surface a small quantity of a black powder, which was reduced to running mercury by trituration alone.

Mercury thus converted to a red powder is known in chymistry and medicine by the name of *mercury precipitated per se*: a title proper enough, as it is actually reduced to the form of a precipitate, and that without any additament; but very improper on the other hand, considering that in reality this mercury is not a precipitate, as not having been separated.

separated from any menstruum in which it was dissolved.

PROCESS III.

To dissolve Mercury in the Vitriolic Acid. Turbith Mineral.

PUT mercury into a glass retort, and pour on it thrice its weight of good oil of vitriol. Set the retort in a sand-bath; fit on a recipient; warm the bath by degrees till the liquor just simmers. With this heat the mercury will begin to dissolve. Continue the fire in this degree till all the mercury be dissolved.

OBSERVATIONS.

The vitriolic acid dissolves mercury pretty well; but for this purpose the acid must be very hot, or even boil; and then too it is a very long time before the dissolution is completed. We have directed the operation to be performed in a retort; because this solution is usually employed to make another preparation called *turbith mineral*, which requires that as much as possible of the acid solvent be abstracted by distillation. Having therefore dissolved your mercury in the vitriolic acid, if you will now prepare the turbith, you must, by continuing to heat the retort, drive over all the liquor into the receiver; and distill till nothing remains but a white powdery matter: then break the retort; pulverize its contents in a glass mortar, and thereon pour common water, which will immediately

ly turn the white matter of a lemon-colour; wash this yellow matter in five or six warm waters, and it will be what is called in medicine *turbith mineral*; that is, a combination of the vitriolic acid with mercury, five or six grains whereof is a violent purgative, and also an emetic; qualities which it possesses in common with the vegetable turbith, whose name it hath therefore taken.

There rises out of the retort, both while the mercury is dissolving, and while the solvent is abstracting, a weak spirit of vitriol; because a great part of the acid remains united with the quick-silver, which at last appears in the form of a white powder: so that, if you do not incline to save the acid which rises on this occasion, you may, instead of drawing off the liquor in a retort, evaporate it in a glass basin set on a sand-bath, which will be much sooner done.

It is very remarkable that, on this occasion, the mercury may be exposed, without any danger of subliming, to a much greater heat than it is capable of bearing when not combined with the vitriolic acid; which shews that this acid hath the property of fixing mercury to a certain degree.

The white matter, that remains after the evaporation of the fluid, is one of the most violent corrosives, and would prove an actual poison if taken internally. By washing it several times in warm water it is freed from a great deal of its acid, and is considerably sweetened. The proof is this; if the water used in washing the turbith be evaporated, there remains after the evaporation a matter in form of a salt, that being set in a cellar runs into a liquor called *oil of mercury*, which is a powerful corrosive. Several authors further direct spirit of wine to be burnt on the turbith, to sweeten it still more.

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If, instead of washing the white matter that remains after the moisture is drawn off, fresh oil of

vitriol be poured on it, and then abstracted as before; this treatment being repeated two or three times, there will at last remain in the retort a matter having the appearance of an oil, which resists the action of the fire, and cannot be desiccated: qualities which are owing to the great quantity of acid particles thus united with the mercury. This oil of mercury is one of the most violent corrosives. The mercury may be separated therefrom, by precipitating it with an alkali, or a metallic substance that hath more affinity than mercury with the vitriolic acid: iron, for instance, may be employed in this precipitation. Mercury thus separated from the vitriolic acid need only be distilled to recover the form of quick-silver.

PROCESS IV.

To combine Mercury with Sulphur. Æthiops Mineral.

MIX a dram of sulphur with three drams of quick-silver, by trituration the whole in a glass mortar with a glass pestle. By degrees, as you triturate, the mercury will disappear, and the matter will acquire a black colour. Continue the trituration till you cannot perceive the least particle of running mercury. The black matter you will then have in the mortar is known in medicine by the name of *æthiops mineral*. An *æthiops* may also be made by fire in the following manner.

In a shallow unglazed earthen pan melt one part of flowers of sulphur: add three parts of running mercury, making it fall into the pan in the form of

small

small rain, by squeezing it through shamoy leather. Keep stirring the mixture with the shank of a tobacco-pipe all the while the mercury is falling: you will see the matter grow thick and acquire a black colour. When the whole is thoroughly mixed, set fire to it with a match, and let as much of the sulphur burn away as will flame.

OBSERVATIONS.

Mercury and sulphur unite together with great ease; cold triture alone is sufficient to join them. By this means the mercury is reduced into exceeding small atoms, and combines so perfectly with the sulphur, that the least vestige thereof is not to be seen.

Sulphur is not the only matter which being rubbed with mercury will destroy its form and fluidity: all fat substances that have any degree of consistence, such as the fat of animals, balsams, and resins, are capable of producing the same effect. This metallic substance, being triturated for some time in a mortar with these matters, becomes at last insensible, and communicates to them a black colour. When thus divided by the interposition of heterogeneous particles, it is said to be *killed*. But mercury doth not contract such an intimate union with these other matters as it doth with sulphur.

The æthiops prepared by fusion is a more perfect and accurate combination of mercury and sulphur than the other: for, the quantity of sulphur directed to be used in making it being much greater than is absolutely necessary to fix the mercury, the redundant sulphur is destroyed by burning, and none left but what is most intimately united with the mercury, and hindered by the union it hath contracted with that metallic substance from being so easily consumed. The æthiops therefore, which is prepared by fusion and burning the sulphur, contains

tains a much greater proportion of mercury than that which is made by simple triture; so that in medicine it ought to be prescribed in different cases, and in smaller doses.

If no more sulphur than is just necessary to kill the mercury be added to it at first, it will be difficult to obtain a perfect mixture; because that quantity is very small: it is better therefore to employ at once the quantity above directed.

P R O C E S S V.

To sublime the Combination of Mercury and Sulphur into Cinabar.

GRIND to powder æthiops mineral prepared by fire. Put it into a cucurbit; fit thereto a head; place it in a sand-bath, and begin with applying such a degree of heat as is requisite to sublime sulphur. A black matter will rise, and adhere to the sides of the vessel. When nothing more will rise with this degree of heat, raise the fire so as to make the sand and the bottom of the cucurbit red; and then the remaining matter will sublime in the form of a brownish red mass, which is true cinabar.

O B S E R V A T I O N S.

Æthiops mineral requires nothing but sublimation to become true cinabar, like that found in quick-silver mines: but our æthiops contains still more sulphur than ought to be in the composition of cinabar; for which reason we have directed the degree of fire applied at first to be no greater than

that which is capable of subliming sulphur. As cinabar, though consisting of mercury and sulphur, is yet much less volatile than either of these substances alone; which probably arises from the vi-riolic acid contained in the sulphur; therefore, if there be any redundant sulphur in the æthiops, which hath not contracted an intimate union with the mercury, it will sublime by itself in this first degree of heat. Some mercurial particles also will rise with it, and give it a black colour.

Cinabar contains no more sulphur than about a sixth or seventh part of its weight: so that, instead of employing the common æthiops to make it, it would be better to prepare one on purpose that should contain much less sulphur; because too much sulphur prevents the success of the operation by blackening the sublimate. Indeed in whatever manner you go about it, the cinabar always appears black at first: but when it is well prepared, and contains no more than its due proportion of sulphur, the blackness is only external. This black coat therefore may be taken off; and then the internal part will appear of a fine red, and, if sublimed a second time, will be very beautiful.

As artificial cinabar hath the same properties with the native, it may be decomposed by the same means; so that, if you want to extract the mercury out of it, recourse must be had to the process above delivered for working on cinabar.

PRO-

PROCESS VI.

To dissolve Mercury in the Nitrous Acid. Sundry Mercurial Precipitates.

PUT into a matrafs the quantity of mercury you intend to dissolve: pour on it an equal quantity of good spirit of nitre, and set the matrafs in a sand-bath moderately heated. The mercury will dissolve with the phenomena that usually attend the dissolutions of metals in this acid. When the dissolution is completed let the liquor cool. You will know that the acid is perfectly saturated, if there remain at the bottom of the vessel, notwithstanding the heat, a little globule of mercury that will not dissolve.

OBSERVATIONS.

Mercury dissolves in the nitrous acid with much more facility, and in much greater quantity, than in the vitriolic; so that it is not necessary, on this occasion, to make the liquor boil. This solution when cold yields crystals, which are a nitrous mercurial salt. If you desire to have a clear limpid solution of mercury, you must employ an *aqua fortis* that is not tainted with the vitriolic or marine acid: for, the affinity of these two acids with mercury, being greater than that of the nitrous acid, they precipitate it in the form of a white powder when they are mixed with the solvent.

Mercury thus precipitated in a white powder, out of a solution thereof in the spirit of nitre, is used in medicine. To obtain this precipitate, which

known

known by the name of the *white precipitate*, sea-salt dissolved in water, together with a little sal ammoniac is used; and the precipitate is washed several times in pure water, without which precaution it would be corrosive, on account of the great quantity of the marine acid which it would contain.

The preparation known by the name of *red precipitate*, is also obtained from our solution of mercury in spirit of nitre. It is made by abstracting all the moisture of the solution, either by distillation in a retort, or by evaporation in a glass basin set on a sand-bath. When it begins to grow dry it appears like a white ponderous mass. Then the fire is made strong enough to drive off almost all the nitrous acid, which, being now concentrated, rises in the form of red vapours. If these vapours be caught in a receiver, they condense into a liquor, which is a very strong and vastly smoking spirit of nitre.

By degrees, as the nitrous acid is forced up by the fire, the mercurial mass loses its white colour, and becomes first yellow, and at last very red. When it is become entirely of this last colour, the operation is finished. The red mass remaining is a mercury that contains but very little acid, in comparison of what it did while it was white: and indeed the first white mass is such a violent corrosive, that it cannot be used in medicine; whereas, when it is become red, it makes an excellent escharotic, which those who know how to use it properly apply with very great success, particularly to venereal sores.

This preparation is very improperly called a *precipitate*: for the mercury is not separated from the spirit of nitre by the interposition of any other substance, but only by evaporating the acid. It is also called *arcanum corallinum*.

It must be observed that mercury, by its union with

with the nitrous acid, acquires a certain degree of fixity: for the red precipitate is capable of sustaining, without being volatilized, a stronger degree of heat than pure mercury can; which, as we observed before, is the property of turbith mineral also.

PROCESS VII.

To combine Mercury with the Acid of Sea-salt. Corrosive Sublimate.

EVaporate a solution of mercury in the nitrous acid, till there remain only a white powder, as mentioned in our observations on the preceding process. With this powder mix as much green vitriol calcined to whiteness, and as much decrepitated sea-salt, as there was mercury in the solution. Triturate the whole carefully in a glass mortar. Put this mixture into a matrafs, so that two thirds thereof may remain empty, having first cut off the neck to half its length: or instead thereof you may use an apothecary's phial. Set your vessel in a sand-bath, and put sand round it as high as the contents reach. Apply a moderate fire at first, and raise it by slow degrees. Vapours will begin to ascend. Continue the fire in the same degree till they cease. Then stop the mouth of the vessel with paper, and increase the fire till the bottom of the sand-bath be red-hot. With this degree of heat a sublimate will rise, and adhere to the inside and upper part of the vessel, in the form of white semi-transparent crystals. Keep up the fire to the same degree till nothing more will sublime. Then let the vessel cool; break it, and take out what is sublimed, which is *corrosive sublimate*.

OBSER

OBSERVATIONS.

In this operation the mineral acids act, and are acted upon, in a remarkable manner. Every one of the three is at first neutralized, or united with a different basis; the vitriolic being combined with iron; the nitrous with mercury, forming therewith a nitrous mercurial salt; and the marine with its natural alkaline basis. The vitriolic and nitrous acids, which are united with metalline substances, being both stronger than the acid of sea-salt, strive to expel it from its basis, in order to combine with themselves; but the vitriolic acid, being the strongest of the two, would take sole possession of this basis exclusive of the nitrous, which would continue united with the mercury, if the marine acid had not a greater affinity than the nitrous, with this metallic substance. This acid therefore being expelled from its basis by the vitriolic acid, and so set at liberty, must unite with the mercury, and separate the nitrous acid from it; which now hath no resource but to unite with the iron deserted by the vitriolic acid. But as all these changes are brought about by the means of a considerable heat, and as the nitrous acid hath not a very firm connection with the iron, it is driven off by the force of the fire; and this it is which we see rise in vapours during the operation. It also carries off with it some parts of the other two acids, but in a very small quantity. After the operation therefore there remains, 1. A combination of the vitriolic acid with the basis of sea-salt; that is, a Glauber's salt: 2 A red martial earth, being that which was the basis of the vitriol: these two substances are blended together, and remain at the bottom of the vessel because of their fixity: 3. A combination of the marine acid with mercury,; both of which being volatile, they ascend together into the upper part

part of the vessel, and there form a corrosive sublimate.

If we reflect on this process with attention, and recollect distinctly the affinities of the different substances employed in it, we shall perceive that it is not necessary to make use of all those matters, and that the operation would succeed though several of them were left out.

First, the nitrous acid may be omitted; since, as hath been shewn, it is not an ingredient in the sublimate, but is dissipated in vapours during the operation. From an accurate mixture therefore of vitriol, sea-salt, and mercury, a corrosive sublimate must be obtained: for as the acid of the vitriol will disengage the acid of sea-salt, the latter will be at liberty to combine with the mercury, and so form the compound we are in quest of.

Secondly, if we make use of mercury dissolved by the nitrous acid, we may omit the vitriol; because the nitrous acid having a greater affinity than the marine acid itself with the basis of sea-salt, and the acid of sea-salt having a greater affinity than the nitrous acid with mercury, these two acids will naturally make an exchange of the bases with which they are united: the nitrous will lay hold on the basis of sea-salt, and form a quadrangular nitre, while the marine acid will join the mercury, and with it form a corrosive sublimate.

Thirdly, instead of sea-salt its acid only may be employed; which being mixed with the solution of mercury in the spirit of nitre, will, by virtue of its greater affinity with that metallic substance, separate it from the nitrous acid, unite with it, and form a white mercurial precipitate, which need only be sublimed to become the combination required.

Fourthly, instead of mercury dissolved in the nitrous acid, mercury dissolved by the vitriolic acid, or turbith, may be used; only mixing sea-salt there-

with:

with: for these two saline substances will mutually decompose each other, by virtue of the affinities of their acids, and for the same reasons that sea-salt and the mercurial nitrous salt decompose each other. The vitriolic acid quits the mercury with which it is combined, to unite with the basis of the sea-salt; and the acid of this salt being expelled by the vitriolic, combines with the mercury, and consequently forms our corrosive sublimate. In this case a Glauber's salt remains after the sublimation.

These several methods of preparing corrosive sublimate are never used, because each of them is attended with some inconvenience; such as requiring too long triture, yielding a sublimate less corrosive than it should be, or a smaller quantity of it. We must, however, except the last; which was invented by the late Mr. Boulduc, of the Academy of Sciences, who found none of these inconveniences attending it*.

Corrosive sublimate may also be made only by mixing mercury with sea-salt, without any additament. This may appear surprizing when we consider that, as acids have a greater affinity with alkalis than with metallic substances, the acid of sea-salt ought not to quit its basis, which is alkaline, to unite with mercury.

In order to explain this phenomenon it must be remembered that sea-salt, when exposed to the fire without additament, suffers a little of its acid to escape. Now this portion of the marine acid unites with the mercury, and forms a corrosive sublimate. Moreover, as there is a pretty strong affinity between the marine acid and mercury, this may help to detach from the sea salt a greater quantity of acid than it would otherwise part with. Neverthe-

* See the Memoirs of the Academy for 1730.

less the quantity of sublimate obtained by this means is not considerable, nor is it very corrosive.

On this occasion we must also mention another combination of the marine acid with mercury; which is made by mixing that metallic substance perfectly with sal ammoniac by the means of triture. Mercury, like all other metals except gold, possesses the property of decomposing sal ammoniac, separating the volatile alkali which serves it for a basis, and combining, by the help of a very gentle heat, with its acid, which is well known to be the same with that of sea-salt. This decomposition of sal ammoniac, by the metalline substances, is a full exception to the first column of Mr. Geoffroy's Table of Affinities, and is the basis of several new medicines invented by the late Comte de la Garaye *.

Corrosive sublimate is the most violent and the most active of all corrosive poisons. It is never used in medicine, but in external applications. It is a powerful escharotic; it destroys proud flesh, and cleans old ulcers; but it must be used by those only who know how to apply it properly, and requires an able hand to manage it. It is not commonly applied by itself, but mixed in the proportion of half a dram to a pound of lime-water. This mixture is yellowish, and bears the name of *Aqua Phagedenica*.

Water dissolves corrosive sublimate, but in a small quantity. If a fixed alkali be mixed with this solution, the mercury precipitates in the form of a red powder. If the precipitate be procured by a volatile alkali, it is white; if by lime-water, it is yellow. This mercurial salt dissolves pretty easily in boiling spirit of wine.

* See the Memoir given in by me on this subject to the Academy of Sciences in the *Memoirs l'Academy* 1754.

PROCESS VIII.

Sweet Sublimate.

TAKE four parts of corrosive sublimate; pulverize it in a glass or marble mortar; add by little and little three parts of mercury revived from cinabar; triturate the whole carefully, till the mercury be perfectly killed, so that no globule thereof can be perceived. The matter will then be grey. Put this powder into an apothecary's phial, or into a matraass, whose neck is not above four or five inches long, leaving two thirds thereof empty. Set the vessel in a sand-bath, and put sand round to one third of its height. Apply a moderate fire at first; and afterwards raise it gradually till you perceive that the mixture sublimes. Keep it up to this degree till nothing more will rise, and then break the vessel. Reject, as useless, a small quantity of earth which you will find at the bottom: separate also what adheres to the neck of the vessel, and carefully collect the matter in the middle, which will be white. Pulverize it; sublime it a second time, in the same manner as before; and in the same manner separate the earthy matter left at the bottom of the vessel, and what you find sublimed into the neck. Pulverize, and sublime a third time, the white matter you last found in the middle. The white matter of this third sublimation is the *Sweet Sublimate*, called also *Aquila*.

OBSERVATIONS.

The acid of sea-salt in the corrosive sublimate is very far from being perfectly saturated with mercury; and thence comes the corrosive quality of this saline compound. But though mercury, as appears by this combination, is capable of imbibing a much greater quantity of acid than is necessary to dissolve it: nay, though it naturally takes up this superabundant quantity of acid, yet it doth not follow from thence that this redundant acid may not combine with mercury to the point of perfect saturation, so as to lose its corrosive acidity.

This is the case in the operation here described. A fresh quantity of running mercury is mixed with corrosive sublimate; and the fresh mercury combining with the super-abounding acid, deprives the sublimate of its acrimony, and forms a compound which comes much nearer the nature of a neutral metallic salt.

Trituration alone is not sufficient to produce an union between the newly added mercury and the acid of the corrosive sublimate: because, generally speaking, the acid of sea-salt cannot dissolve mercury without the help of a certain degree of heat, and unless it be reduced into vapours.

Thus, though the newly added mercury becomes invisible by trituration, and seems actually combined with the corrosive sublimate, yet the union is not intimate. There is only an interposition of parts, but no true dissolution of the newly added mercury by the super-abundant acid of the corrosive sublimate. For this reason the mixture must be sublimed; and by this sublimation only is the true union effected. Nor is one single sublimation sufficient: no less than three are necessary to deprive the sublimate of the corrosive quality which renders it poisonous. After the third sublimation

the sublimate being put upon the tongue gives no considerable sensation of acrimony ; nor doth it retain any more of its former activity than is requisite to make a gentle purgative, when administered from six to thirty grains for a dose.

If a less quantity of mercury than that above directed be mixed with the corrosive sublimate, the super-abundant acid will not be sufficiently saturated : and the less mercury is added, the more of its corrosive virtue will the sublimate retain.

If, on the contrary, a greater quantity of mercury be added, there will be more than the acid can possibly dissolve, and the superfluous quantity will remain in its natural form of quick-silver. It is better therefore to err in the excess than in the defect of the proportion of mercury to be added ; because the corrosive sublimate will take up no more than is necessary to dulcify it.

Part of the acid of the corrosive sublimate is also dissipated in vapours during the operation ; and it is necessary to allow room for these vapours to circulate, and a vent to give them passage, or else they will burst the vessels. These are our reasons for leaving an empty in the subliming vessels, and for having their necks no more than five or six inches long.

The matter which sublimes into the neck of the vessel is always very acrid ; for which reason it must be separated from the sweet sublimate. There remains also at the bottom of the matrafs an earthy, reddish matter ; which probably comes from the vi-riol employed in making the corrosive sublimate. This matter must likewise be rejected as useless after every sublimation.

PROCESS IX.

The Panacea of Mercury.

PULVERISE some sweet sublimate, and sublime it in the same manner as you did thrice before. Repeat this nine times. After these sublimations it will make no impression on the tongue. Then pour on it aromatic spirit of wine, and set the whole in digestion for eight days. After that decant the spirit of wine, and dry what remains, which is the *Panacea of Mercury*.

OBSERVATIONS.

The great number of sublimations, which the sweet sublimate is made to undergo, sweeten it still more, and to such a degree that it leaves no sensation on the tongue, nor hath any purgative virtue.

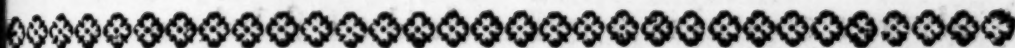
The spirit of wine, in which it is digested after all the sublimations, is designed to blunt still more the sharpness of any acid particles that may not have been sufficiently dulcified by the preceding sublimations.

As mercury is the specific remedy for venereal disorders, fundry preparations thereof have been attempted with a view to produce different effects. Sweet sublimate is purgative; and for that reason is not quite proper for procuring a salivation, because it carries off the humours by stool. The panacea of mercury, which, on the contrary, is not purgative, may raise a salivation when taken inwardly.



P A R T II.

S E C T I O N III.

Of Operations on the SEMI-METALS.

C H A P. I.

Of ANTIMONY.

P R O C E S S I.

To separate Antimony from its Ore by Fusion.

HAVING drilled some small holes, of about two lines diameter, in the bottom of a crucible, put into it your antimonial ore broken into little bits, about the size of a hazel nut; set it on its cover; set the crucible thus prepared in the mouth of another crucible, and close the joints with lute.

At the distance of half a foot from this compound vessel, place bricks all round, so as to form a furnace; the sides of which must rise as high as the brim of the uppermost crucible.

Let

Let the bottom of this furnace be filled with ashes, up to the top of the lower crucible, and the rest of the furnace with lighted coals. Blow the fire, if it be necessary with bellows, till the upper crucible become red. Keep it up in this degree for about a quarter of an hour. Then take your vessels out of the furnace, and you will find the antimony collected in the bottom of the lower crucible, having run through the holes of the upper one.

OBSERVATIONS.

The ore of antimony is one of the most fusible: it always contains a great deal of sulphur, and cannot sustain a fire of any force without being dissipated into vapours. It requires no additament to flux it: for it is not necessary, on this occasion, that the earthy and stony matters mixed therewith be brought to fusion. It is sufficient that the antimonial part be melted; which, as soon as it becomes fluid, is carried by its weight to the lower part of the crucible. Thus it is separated from all heterogeneous matters; which are left in the upper crucible, while it passes through the holes in its bottom, and forms a mass in the lower.

The precaution of closing all the apertures of both crucibles is necessary, on account of the volatility of this mineral: and that the antimony, when once melted, may not continue exposed to a great heat, it is made to run down into a vessel surrounded with ashes only, and by that means very little affected with heat; ashes being one of those solid mediums that transmit least of it.

PROCESS II.

The common Regulus of Antimony.

Reduce crude antimony to powder. Mix it with three fourths of its weight of white tartar, and half its weight of refined salt-petre, both pulverized. Into a large crucible made red-hot in the fire, throw a spoon-full of your mixture, and cover it. There will be a very considerable detonation. When it is over, throw in a second spoon-full of your mixture, and cover the crucible as before: this will produce a second detonation. Go on thus, till you have thrown in all your mixture.

When the whole has thus fulminated, increase the fire so as to bring the matter into fusion; that being done, take the crucible out of the furnace, and immediately pour its contents into an iron cone heated and greased with tallow. Strike the floor and the cone some gentle blow with a hammer, to make the regulus precipitate; and when the matter is fixed and cold, invert the cone and turn it out. You will see it consist of two distinct substances; the uppermost of which is a saline scoria, and the undermost the reguline part. Strike this with a blow with a hammer, in the place where these substances join, and you will by this means separate the scoria from the regulus; the latter of which will have the form of a metallic cone, on whose base you will observe the signature of a bright

OBSER-

OBSERVATIONS.

Antimony, though separated by a former fusion from the earthy and stony parts of its ore, must nevertheless be still considered as an ore, on account of the great quantity of sulphur it contains, which mineralizes the metalline part or regulus. Therefore if you desire to have this regulus pure, you must separate it from the sulphur that is combined with it. This may be done several ways. The method above proposed is one of the readiest and easiest, though not altogether free from inconveniencies, as we shall shew.

The salt-petre in the mixture detonates by means of the sulphur of the antimony, which it consumes, and from which it separates the reguline part: but lest it should also consume some of the phlogiston which gives the regulus its metalline form, tartar is added; because it contains a great deal of inflammable matter, and so is capable of furnishing enough for the detonation of the nitre, or rather for restoring to the metallic earth of the Antimony the phlogiston that may be consumed by the Nitre.

If we consider what passes in this operation we shall soon be convinced that a great deal must be lost in it, and that we do not thereby obtain near the whole of the Regulus that the Antimony is capable of yielding: for 1. the regulus of antimony being a volatile substance, much of it must be dissipated during the detonation; and so much the more as the detonation is frequently repeated, and continued for a considerable time. The flowers that may be collected by presenting cold bodies to the smoke that rises in the operation, and which may be reduced to a regulus by the addition of a phlogiston, sufficiently prove what is here advanced.

2. All the sulphur of the antimony is not consumed

turned by the nitre on this occasion; and moreover, the acid of that part thereof which is burnt, uniting with some of the alkali produced by the deflagration of the nitre and tartar, forms a vitriolated tartar, which meeting with a sufficient quantity of phlogiston in the mixture produces new sulphur. Now this sulphur, whether not consumed, or re-produced, in the operation, combining with the alkali forms a liver of sulphur; and that dissolves part of the regulus, which by this means remains confounded with the scoria. The proof of this is, that, if the scoria be mixed with filings of iron, and fused a second time, you will find at the bottom of the crucible a button of regulus, which it contained, and which is separated therefrom by the interposition of the iron. We shall say more on this subject in the process for making the martial regulus, which immediately follows this. If, instead of melting the scoria with iron filings, we pulverize it, boil it in water, and then pour an acid into that water; the liquor will instantly grow turbid, and a sulphureous precipitate will fall, commonly called the *golden sulphur of antimony*; which is nothing else but common sulphur still combined with some particles of the regulus: a new proof of what we advanced concerning the production of liver of sulphur in this operation.

As regulus of antimony is of no great value, the loss sustained in this process is seldom regarded. However, we shall have occasion, in the sequel, to point out a method of obtaining this regulus with less disadvantage.

PROCESS III.

Regulus of Antimony precipitated by Metals.

PUT one part of small iron nails into a crucible, and set it amidst burning coals, in a melting furnace. When the iron is thoroughly red-hot, and begins to grow white, add thereto little by little, and at several times, two parts of crude antimony in powder. The antimony will immediately flow and unite with the iron. When the antimony is entirely melted, add thereto, at several times, the fourth of its weight of pulverized nitre; a detonation will ensue, and the whole mixture will be in fusion.

After you have kept the matter in this condition for some minutes, pour it into an iron cone, first heated and tallowed. Strike the sides of the cone with a hammer, that the regulus may fall to the bottom; and, when all is cold, separate it from the scoria by a blow with a hammer. Melt this first regulus again in another crucible, adding a fourth part of its weight of crude antimony. Keep the crucible close shut, and give no more heat than is necessary to melt the matter. When it is in perfect fusion, add to it at several times, as you did before, the sixth part of its weight of pulverized nitre; and, in half a quarter of an hour after this, pour the whole into a cone as you did the first time.

Lastly, melt your regulus over again a third or even a fourth time, always adding a little nitre which will detonate as before. If after all these fusions you pour the regulus into an iron cone, you will find it very beautiful, and the statim formed: It will be covered with a semi-transparent

ent, lemon-coloured scoria. This scoria is extremely acrid and caustic.

OBSERVATIONS.

Though regulus of antimony unites very readily with sulphur, and is always found combined therewith in the earth, we must not thence conclude that it hath a greater affinity than other substances with that mineral: On the contrary, all the metals, except gold, have a greater affinity than this semi-metal with sulphur. Hence it follows that all the metals, except gold, are capable of decomposing antimony, and separating the sulphureous part from the metalline; so that, instead of employing iron, as in our process, copper, lead, tin, or silver, may be used; and a regulus obtained by means thereof.

But as iron is, of all the metallic substances, that which hath the greatest affinity with sulphur, it is on this occasion preferred to the rest. And from hence two advantages arise: the first is, that the operation is performed sooner and with greater ease; the second, that the regulus is purer, and contains less of the precipitating metal. For as a general rule, that, when one metallic substance is employed to precipitate another, the precipitated substance is always a little adulterated by admixture of some particles of the precipitant. Now, the greater affinity the precipitant hath with the matter united to that which is to be precipitated, the less doth the precipitate retain of the precipitant.

In this process the iron melts very easily by means of the union it contracts with the sulphur; which, as we observed before, hath the property of rendering this metal very fusible, though of it the most refractory of all.

The scoria found on the regulus of the first fusion

tion is a combination of iron with the sulphureous part of the antimony. This scoria is extremely hard, and not to be separated from the regulus without some trouble. The nitre added, being alkalized and uniting therewith, renders it a little softer, and gives it the property of relenting in the air. Any alkaline salt may be substituted for the nitre.

The nitre that is alkalized in the operation, or the alkali that is added, procures moreover another advantage; namely, that, by uniting with part of the sulphur of antimony, it produces a liver of sulphur, which dissolves the iron, retains it, and hinders that which is not yet combined with pure sulphur from uniting so readily with the regulus as it otherwise would do.

Lastly, the addition of nitre, or an alkali, contributes greatly to promote the fusion, to render it more perfect, and to procure a more complete precipitation of the regulus.

The second fusion which the regulus is made to undergo is intended to purify it from any mixture of iron. When the fresh antimony added on that occasion comes to melt with the regulus, the sulphur contained in the antimony joins with the ferruginous parts in the regulus; and the iron becoming lighter by this union is thrown up to the surface of the matter. There it forms a sort of scoria, with which a good deal of antimony is mixed; the regulus not being wholly precipitated, because there is not iron enough in the mixture for that purpose. The salt-petre added here produces the same effect as in the first fusion.

But if, on one hand, the regulus precipitated in the first fusion be purified, by this addition of fresh antimony, from most of the iron with which it was alloyed; on the other hand this same regulus cannot be kept from re-uniting with some sulphureous parts.

In order therefore to separate it entirely from these, it must be melted over again once or twice more, and a little nitre added each time, to consume them by deflagration. But this cannot be done without consuming also some of the very phlogiston which gives the regulus its metalline form: whence it comes to pass that part of the regulus is converted to a calx, which by means of the alkalized nitre is turned into glass; and it is this glass which mixing with the scoria gives it the yellow colour observed therein. This yellow colour may also be in part produced by some ferruginous particles, of which a small quantity always remains combined with the regulus, notwithstanding its former depuration by antimony.

It is of no use to repeat the fusions of the regulus oftener than is above proposed, or to add fresh nitre with a view to consume the sulphur it may still contain: for after the second fusion it contains none at all, and retains only the phlogiston necessary to give it the metalline form. So that, by prosecuting the matter further, you would only calcine and destroy the regulus to no manner of purpose.

From what hath been said it is plain that, even by this process, we do not obtain all the regulus which our antimony is capable of yielding; seeing part of it is destroyed by the fusions it must necessarily undergo with nitre, in order to its purification. We shall give a process for obtaining from antimony the greatest quantity of regulus it can possibly be made to yield, after we have treated of its calcination, which is in some sort the first step of that process.

PROCESS IV.

The Calcination of Antimony.

TAKE an unglazed earthen vessel, wider at top than at bottom; put into it two or three ounces of crude antimony finely pulverized. Set this vessel over a weak charcoal fire, and increase the heat till you see the antimony begin to smoke a little. Continue the fire in this degree, and keep incessantly stirring the antimony with the shank of a tobacco pipe all the while it is upon the fire.

The powder of antimony, which, before calcination, was of a brilliant colour inclining to black, will become dull, and look like an earth. When it comes to have this appearance raise your fire till the vessel be red-hot, and keep it up in this degree till the matter cease entirely to smoke.

OBSERVATIONS.

Antimony, as hath been already said, is a sort of ore consisting of a metalline or reguline part mineralized by sulphur.

The design of this calcination is, by the action of fire, to dissipate the sulphureous part, which is the most volatile, in order to separate it from the metalline part. It is evidently a real torrefaction; but the operation is very difficult, and requires a good deal of attention: for antimony very easily melts, while at the same time it is necessary to obtain success that it do not melt; because when the matter is in fusion the sulphur requires a much greater degree of heat to carry it off. Now, as regulus of antimony itself is very volatile, a good deal of it would be dissipated along with the sulphur.

phur, if it were exposed to the degree of heat necessary to carry off the sulphur when the mass is melted.

Therefore if it happen that the antimony begin to melt during the calcination, which is easily perceived by its running into clots, it must be taken off the fire, and the clotted parts be again pulverized; after which the calcination is to be prosecuted with a less degree of heat.

When the antimony has lost all its brightness, and is become like an earth, it is time to augment the degree of heat, in order to complete the calcination; because the last portions of the sulphur are the most difficult to raise. Moreover the inconveniences just mentioned are not now to be apprehended: for, as the great fusibility of the reguline part is owing to the sulphur, what remains, after you have dissipated the greatest part of the sulphur, is much less fusible; and, as the redundant sulphur of the antimony cannot be driven off, without dissipating at the same time a good deal of the phlogiston necessary to metallize its regulus, the matter that remains comes much nearer to the nature of a calx, than to that of a metalline substance; and consequently partakes of the nature of all metallic calxes, which is to be very fixed.

Antimony may also be calcined by mixing with that mineral an equal quantity of charcoal-dust. As charcoal is incapable of fusion, it prevents the antimony from clotting, as well as from losing so much of its metallizing phlogiston as it otherwise would: and hence it comes to pass that the calx of antimony, prepared in this manner, comes nearer to the nature of a regulus, than that which is prepared without addition.

If you happen to raise the fire too much, in this calcination with charcoal-dust, the calx will be partly reduced to a regulus, by means of the phlogiston which the charcoal furnishes: and then the regulus

regulus will be dissipated in vapours, especially as this calx, which comes very near the nature of a regulus, is not so fixed as that prepared without addition. For this reason it always continues to smoke, even when it contains no superfluous sulphur : and therefore you must not wait till it ceases to smoke before you put an end to your calcination ; for you will lose a great deal of it in vapours. It is time to stop when the vapours that rise from it, while it is moderately red, do not smell of burning sulphur.

P R O C E S S V.

Calx of Antimony reduced to a Regulus

MIX the calx of antimony, which you intend to reduce, with an equal quantity of black soap. This mixture will make a thin paste. Put it little by little into a crucible, previously made red-hot amidst live coals. Thus let the soap burn till it ceases to emit any oily smoke. Then cover the crucible ; make the fire strong enough to melt the matter, and you will hear it effervesce and boil. When this noise is over let the crucible cool, and then break it : you will find in it a beautiful scoria marked with circles of several colours ; and under that a button of Regulus, which is not yet quite pure, and must be purified in the following manner.

Pound this Regulus, and mix it with half its weight of an antimonial calx as perfectly desulphurated as possible. Put it into a crucible, and cover it : melt the whole, so that the surface of the melted matter may be smooth and uniform. Let the crucible cool, and then break it : you will find in it a beautiful button of very pure Regulus, covered with a scoria having the appearance of an opaque

glass

glafs, or a kind of greyish enamel, moulded on the finely radiated furface of the regulus.

OBSERVATIONS.

Of all the metalline calxes that of antimony is moft eafily reduced. Any matter that contains the phlogifton, even charcoal-duft alone is fufficient to procure it the form of a regulus, without the addition of any thing to facilitate its fufion; becaufe this calx, which is not of itfelf altogether refractory, becomes ftill more fufible as it combines with the phlogifton, and approaches to the reguline ftate.

Though all inflammable matters are capable of procuring the reduction of the calx of antimony, yet there are fome with which the operation fucceeds better, and produces a greater quantity of regulus, than it does with others. Fatty matters, joined with alkalis, are thofe which answer beft in this reduction, as they do in moft others. The black flux, for inftance, is very proper for this purpofe: but Mr. Geoffroy, who made many experiments on antimony, found by repeated trials that black soap is ftill fitter for it, and that a greater quantity of regulus was obtained by its means, than by any other reducing flux whatever. The procefs here given is taken from one of the Memoirs on this fubject, which he laid before the Academy of Sciences.

Black soap is made of the lye of a fixed alkali, fuch as pot-afh for inftance, with quick-lime, incorporated by boiling with oil of lint-feed, rape-feed, or hemp-feed, and fometimes alfo with animal fat. The oily matters, contained in this reducing flux, are firft burnt and charred to a coal in the crucible. As foon as they are brought to this ftate, the crucible is covered, and the fire is encreafed, till the matters melt. At that inftant the reduction begins

to take place; and the bubbling noise observed is an effect thereof.

The regulus obtained by this first fusion is not yet very pure, being adulterated with the mixture of some unmetallic earth that was contained in the antimony, and with a portion of the calcarious earth of the soap.

Mr. Geoffroy found that his regulus was contaminated with this substance, by putting it into water, for on that occasion he observed a very brisk ebullition about the reguline buttons, which sometimes lasted above four and twenty hours; and on examining them with a glass, he discovered some little holes, imperceptible to the naked eye, through which the water entered, to unite with the lime retained in the internal parts of the regulus, which having been re-calcined in the operation required to be flaked.

This regulus may be purified by simple fusion, without any additament, because the particles of lime, being lighter than those of the regulus, will be thrown up to the surface, on which they will form a sort of scoria. But Mr. Geoffroy took notice that, in this case, the surface of the regulus is never very neat; that it is always sullied with a very adhesive scoria, and that no star is formed upon it. Besides, the regulus must be kept a long while in a very thin fusion, that the heterogeneous matters, which hinder the perfect re-union of its parts, may have time to rise to the surface by their lightness. But the longer the regulus is kept in fusion, the more of it evaporates, because of its volatility. He was therefore obliged to have recourse to other means.

We have in the process described the method which succeeded best with Mr. Geoffroy. It consists in melting the regulus over again, with the addition of a little fresh calx of antimony thoroughly freed from its sulphur. This calx be-
ing

ing in its nature easily vitrifiable, and combining with the earthy parts that deprave the regulus, and which cannot be vitrified without addition, scorifies these matters, and with them forms the opaque glass, or kind of enamel which is found over the regulus purified in this manner.

The star on that part of the regulus of antimony, which was contiguous to the scoria, is a mark of its purity, and a proof that the operation was well performed. This star is nothing but a particular disposition of the parts of the antimony, which have the property of running naturally into facets and needles. The perfect fusion, both of the regulus and the scoria that covers it, leaves the parts of the regulus at liberty to range themselves in this order. This disposition appears not only on the upper surface of the regulus, but, if you break the button, you find the same in its internal parts. There are some round pyrites whose insides have nearly the same appearance, and seem to consist of rays issuing from a common center.

The quantity of regulus obtained by Mr. Geofroy's process is more than double of what is procured in the common way, which yields but about four ounces in the pound; whereas this gives from eight to ten ounces.

When antimony is calcined with charcoal dust, what remains after the dissipation of all the sulphur is not, properly speaking, a calx of antimony; but a sort of regulus quite formed, and differing from the common regulus only in that its parts are disunited, and not collected into a mass. For if this pretended calx of antimony be melted, it directly coalesces into a regulus, without the addition of any inflammable matter fit to procure its reduction. Indeed less regulus is obtained by this means than when a reductive is added: but nevertheless this experiment still proves what I advanced; seeing regulus of antimony cannot be melted without

without losing more or less thereof, either because some of it is dissipated in vapours. or because part of it loses its phlogiston in the fusion, and so is converted into a calx.

PROCESS VI.

*Antimony calcined with Nitre. Liver of Antimony.
Crocus Metallorum.*

PUlverize and mix perfectly together equal parts of nitre and antimony: put the mixture into an iron mortar, and cover it with a tile, which however must not shut it quite close, With a live coal set fire to the matter in the mortar, and immediately withdraw it. The mixture will flame, with great detonation; which being over, and the mortar cooled, invert it, and strike its bottom to make all the matter fall out. Then, by a blow with a hammer, separate the scoria from the shining part, which is the *liver of antimony*.

OBSERVATIONS.

In this operation the nitre takes fire and detonates with the sulphur of the antimony; and nothing remains but the metallic earth of the mineral, which meeting with no substance to restore its phlogiston cannot take the form of a regulus; but, being combined with a large quantity of fused saline matters begins itself to flow, and forms a sort of vitrification; which however is not a complete one, because the matters do not continue long enough in fusion, but cool too soon. This preparation of antimony is a violent emetic. It is used to make emetic wine and tartar emetic: it is also given in substance to horses.

The saline matters found after the operation in

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the form of a scoria, or perhaps confounded with the liver of antimony, are combinations of fixed nitre, partly with the acid of the burnt sulphur, forming a neutral salt of the same kind as vitriolated tartar, and partly with some unburnt sulphur, forming a sort of liver of sulphur that contains a little regulus. It is usual to pulverize this liver of antimony and wash it with water, in order to dissolve and carry off all the salts. When thus pulverized and washed it is called *crocus metallorum*. If liver of antimony be melted with any inflammable matter, it will be reduced to a regulus; because it is nothing but a metalline calx half vitrified.

P R O C E S S VII.

Another Calcination of Antimony with Nitre. Diaphoretic Antimony. Materia Perlata. Clyffus of Antimony.

MIX one part of Antimony with three parts of nitre; project this mixture by spoonfuls into a crucible kept red-hot in a furnace. Each projection will be attended with a detonation. Continue doing this till you have used all your mixture: then raise the fire, and keep it up for two hours; after which throw your matter into a pan full of hot water. Let it lie steeping in water kept hot for a whole day. Then pour off the liquor: wash the white powder you find at bottom in warm water; and repeat the ablutions till the powder become insipid. Dry it, and you have *diaphoretic antimony*.

O R S E R V A T I O N S.

THIS operation differs from the preceding one, in respect of the quantity of nitre deflagrated with the antimony. In the former we added one part only of nitre to one part of antimony; but in this three parts of nitre are put to one of the mineral;

and the calx resulting from this mixture is of course very different from the other.

In the first place, liver of antimony hath a reddish colour; whereas diaphoretic antimony is very white. Secondly, liver of antimony is in a manner half vitrified; diaphoretic antimony is, on the contrary, in the form of a powder, the parts of which have no connection together.

The reason of these differences will easily appear, if we consider, that, liver of antimony being the result of calcination with one part of nitre only, which is not sufficient to consume all the sulphur of the mineral, what remains after the detonation is not entirely deprived of its phlogiston; from whence arise the colour it retains and the ease with which it flows in the fire: but that, when three parts of nitre are added instead of one, this quantity is not only sufficient to consume all the sulphur and the phlogiston of the antimony, but even more than enough; seeing that, after the operation, some nitre is still found undecomposed.

The calx of antimony, prepared by calcining it with three parts of nitre, it therefore deprived of all its phlogiston. This is the cause of its whiteness, and the reason why it is not half vitrified by the operation, as liver of antimony is: for we know that the more a metallic calx is deprived of its phlogiston, the less fusible and the less vitrifiable it is. This calx of antimony bears the name of *diaphoretic antimony*, or *diaphoretic mineral*; because, being neither emetic nor purgative, it is thought to have the virtue of promoting perspiration.

Antimony may be calcined with various proportions of nitre, between that used to make liver of antimony, and this with which diaphoretic antimony is prepared; and from these calcinations will result calxes possessed of properties, both chymical and medical, of an intermediate nature between the

extremes

extremes of those two preparations. The nearer the proportion of nitre comes to that employed in preparing liver of antimony, the more will the resulting calx resemble that preparation; and in the same manner, a calx prepared with a greater proportion of nitre will so much the more resemble diaphoretic antimony, as the proportion of nitre used comes nearer three parts of nitre for one of antimony.

It is not necessary that antimony in substance be employed to make the diaphoretic mineral: you may, if you please, make use of it's regulus. But as the regulus contains no sulphur, nor any more phlogiston than is requisite to secure it's metalline form, it is needless to put three parts of nitre to one of regulus; an equal quantity thereof being sufficient.

The matter is projected by spoonfuls, to the end that, by gradual and repeated detonations; the antimony may be more perfectly calcined: It is also with a view to destroy entirely the small remainder of phlogiston, which may have escaped the action of the nitre, that the matter is kept red hot in the crucible for two hours,

The whole is afterwards thrown into hot water and left steeping therein for several hours, with design to give the water time to dissolve all the saline matters that are mixed with the diaphoretic calx. When crude antimony is used in making this preparation, these saline matters are 1. an alkalized nitre; 2. a neutral salt formed by the union of the acid of sulphur with part of that alkali, as in the preparation of liver of antimony; 3. a portion of undecomposed nitre.

The water in which the diaphoretic is washed takes up moreover a portion of the calx of antimony, which is exceeding finely attenuated, and continues united with the fixed nitre, and suspended therewith in the liquor. This matter is to be separated.

parated from the fixed nitre, by mixing the water wherein it is dissolved with an acid, which unites with the alkali, and precipitates this matter in the form of a white powder, to which the name of *materia perlata* hath been given. Because it is precipitated in the same manner as the golden sulphur of antimony, and, like that, is found in the water with which the saline matters are washed out, after the detonation of nitre with antimony, some chymists have given it, though very improperly, the name of the *fixed sulphur of antimony*.

This matter is a true calx of antimony, and differs from diaphoretic antimony in nothing but it's being still more perfectly calcined. It is so indeed to such a degree that it is impossible to restore its metalline form, or reduce it to a regulus, by the addition of an inflammable matter. Diaphoretic antimony, on the contrary, may be re-metallized, by supplying it with phlogiston: but it must be observed that, in whatever manner you go about this, you will obtain a much smaller quantity of regulus, than when you use a calx of antimony prepared with a smaller quantity of nitre.

If you attempt to reduce either liver of antimony or diaphoretic antimony, great care must be taken to wash them thoroughly, in order to free them from every thing saline: for, without this precaution, the acid of the sulphur, having, as was observed, formed a neutral salt with the alkali of the nitre, will combine with the inflammable matter added to revivify the calx of antimony and reproduce a sulphur; which, uniting afterwards with the same alkali, will produce a liver of sulphur, that will dissolve part of the regulus, hinder it's precipitation, and greatly lessen the quantity which might otherwise be expected.

A particular sort of diaphoretic antimony is sometimes prepared for medical uses, which hath

a purgative quality : it is not washed at all, and is therefore called *unwashed diaphoretic mineral*.

Diaphoretic antimony may also be prepared in close vessels, by means of which the vapours that rise during the operation are retained. For this purpose a tubulated retort is employed, having a series of adopters fitted to it. The retort is placed in a furnace, and heated till its bottom become red : then a very small quantity of the mixture, for making diaphoretic antimony, is introduced through the tube in the upper part of the retort, and the tube immediately stopped. A donation ensues, and the vapours expand themselves into the adopters, where they condense. This is repeated till the intended quantity of matter be used. After the operation some white flowers are found sublimed in the neck of the retort, and a small quantity of liquor in the recipients. This liquor is acid. It consists of some of the acid of the nitre, which the acid of the sulphur hath expelled from its basis, and also a little of the acid of the sulphur carried up by the heat before it could combine with the basis of the nitre. This liquor is called *clyffus of antimony*. The name of *clyffus* is given to all liquors in general that are prepared by this method.

The white flowers found in the neck of the retort are flowers of antimony ; that is a calx of antimony forced up by the heat, and by the impetus of the detonation. These flowers may be reduced to a regulus. What remains in the retort is the same with the matter that remains in the crucible, wherein the mixture of nitre and antimony for making diaphoretic antimony hath been deflagrated.

Neither diaphoretic antimony nor the pearly matter are soluble in any acid.

P R O C E S S VIII.

Calx of Antimony Vitrified.

TAKE any quantity you please of calx of antimony, made without addition; put it into a good crucible, which set in a melting furnace: kindle the fire gradually, and leave the crucible uncovered at the beginning.

A quarter of an hour after the matter is red-hot, cover the crucible, and excite the fire vigorously till the calx melt. You may know when it is thoroughly melted, by dipping into the crucible an iron wire, to the end of which a little knob of glass will adhere, if the matter be in perfect fusion. Keep it in fusion for a quarter of an hour, or rather longer if your crucible can bear it. Then take it out of the furnace, and immediately pour out the melted matter on a smooth stone, made very hot for the purpose: it will presently fix into a yellow glass.

O B S E R V A T I O N S.

ALL the calxes of antimony, when exposed to a violent fire, are converted into glass; but not all with the same facility. In general, the more of their phlogiston they have lost in the calcination, the more difficult is their vitrification. This causes also a difference in the colour of the glass, which will be of so much a deeper yellow, and the nearer to a red, the less the antimony was calcined.

It frequently happens, when we employ a calx of antimony which is not sufficiently deprived of its phlogiston, that we find in the crucible a button of regulus, which being heavier than the glass, al-

ways

ways lies at the bottom. With a view to avoid this inconvenience, and to dissipate completely the excess of phlogiston that may still be left in the calx of antimony, we direct the crucible to be left uncovered for some time, at the beginning of the operation. If, notwithstanding this precaution, any regulus be still found at the bottom of the crucible, and you resolve to vitrify it, the crucible must be returned to the furnace, and the fusion continued; by which means the regulus will at last be converted into glass.

If, on the contrary, you meet with any difficulty in effecting the vitrification, on account of your having employed a calx that hath lost too much of its phlogiston, such as diaphoretic antimony, or the pearly matter, the fusion may be greatly facilitated by throwing into the crucible a little crude antimony.

Glass of antimony is a most violent emetic. This glass, as well as liver of antimony, is employed in preparing emetic wine, and emetic tartar.

It may be re-suscitated, like the calxes of antimony, into a regulus, by re-uniting it with a phlogiston. For this purpose it must be finely pulverized, thoroughly mixed with some black flux, and melted in a covered crucible. This glass, as well as that of lead, hath the property of greatly promoting the vitrification of matters that are to be scorified.

PROCESS IX.

Kermes Mineral.

BREAK any quantity you will of Hungarian antimony into little bits: put it into a good earthen coffee-pot: pour on it twice its weight of rain-

rain-water, and a fourth part of its weight of well filtered liquor of nitre fixed by charcoal. Boil the whole briskly for two hours, and then filter the liquor. As it cools it will acquire a red-colour, grow turbid, and leave a red powder on the filter.

Return your antimony into the coffee-pot. Pour on it as much rain-water as before, and three fourths of the former quantity of the liquor of fixed nitre. Boil it again for two hours, and then filter the liquor. It will again depose a red sediment. Return your antimony into the coffee-pot: pour on it the same quantity of rain water, and half the first quantity of the liquor of fixed nitre. Boil it again for two hours, and filter the liquor as formerly. Wash all these sediments with warm water, till they become insipid; then dry them, and you have the *Kermes Mineral*.

OBSERVATIONS.

If you recollect what we said concerning the property which fixed alkalis possess of uniting with sulphur, both by fusion, and, when those salts are resolved into a liquor, by boiling, and of forming therewith a liver of sulphur, which dissolves all metalline substances, you will readily comprehend the nature of this kermes.

Antimony consists of a sulphureous and a reguline part. Therefore, if this mineral be boiled in a solution of a fixed alkali, such as nitre fixed by charcoal, the alkali will dissolve the sulphur of the antimony, and form therewith a liver of sulphur; which in its turn will dissolve the reguline part. Now, kermes mineral, prepared as above directed, is no other than a liver of sulphur combined with a certain quantity of regulus of antimony.

Mr. Geoffroy hath set this truth in the clearest light, by his accurate analysis of the kermes mineral.

neral. The experiments he made on that subject are circumstantially related in several memoirs printed in the volumes of the academy for 1734 and 1735. By combining acids with the kermes he demonstrated, 1. the existence of sulphur in this compound; having separated from it a burning sulphur, which cannot be mistaken for any other than the sulphur of antimony. In order to obtain this sulphur pure, an acid must be employed that will not only absorb the alkali, but also perfectly dissolve the reguline part that might otherwise remain united with the sulphur. *Aqua Regia* was the acid which succeeded best with Mr. Geoffroy. 2. He also proved that there is a fixed alkali in the composition of the kermes; seeing the acids with which he precipitated the sulphur became neutral salts, and just such as those very acids combined with a fixed alkali would have constituted: that is, the vitriolic acid produced a *sal de gubus*; the nitrous acid a regenerated nitre; and the marine acid a regenerated sea-salt. 3. Mr. Geoffroy demonstrated the reguline part of antimony to be an ingredient in the kermes; having procured therefrom an actual regulus of antimony, by fusing it with the black flux.

In preparing the kermes it is necessary to renew the liquor from time to time, as above directed; because, when it is once impregnated with kermes to a certain degree, it can take up no more; and consequently the same liquor cannot operate again on the antimony. Experience hath shewn, that, if the doses above prescribed be applied, the liquor will after two hours boiling be sufficiently saturated with kermes.

If the liquor in which the kermes is dissolved be filtered while it is very hot, and almost boiling, it leaves nothing on the filter; the kermes passing through with it: but as it cools it grows turbid, and gradually deposits the kermes. Therefore it ought

ought not to be filtered till it be cold ; or, if it be filtered, while it is boiling hot, in order to separate from it some coarse particles of antimony not yet converted into kermes, it must be filtered a second time when it is cold, in order to get the kermes.

Though in the method usually practised for making kermes, the antimony is boiled only thrice, yet it does not follow that more kermes may not be obtained from it, or that but little more would be obtained by a fourth and fifth boiling : on the contrary it would yield considerably more. Mr. Geoffroy observed that he got more kermes by the second boiling than by the first, and still more by the third than by the second ; and that the yield goes on increasing in this manner to a very great number of times, which he hath not determined. This increased effect arises from hence, that by multiplying the frictions of the little bits of antimony against each other, new surfaces are exposed to the action of the alkaline liquor, and furnish it with more sulphur ; while the addition of this sulphur renders the hepar more active and more penetrating ; or, if you please, produces a new hepar every time the matters are boiled. When the alkaline liquor is once saturated with kermes, it ceases to act, and forms no new hepar ; but it doth not follow that its virtue is quite exhausted. To restore its ability of acting as well as at first, or nearly so, you need only let it cool, and deposite the kermes dissolved in it. We owe this singular observation also to Mr. Geoffroy : he had the patience to go through no less than threescore and ten boilings with the same liquor, without adding any thing but rain water, to supply the place of what was dissipated by evaporation ; and he always obtained a pretty considerable quantity of kermes by each boiling, for the reason given above.

Boiling is not the only means of making kermes. Mr. Geoffroy found the way of making it by fusi-

on. For this purpose you must mix accurately one part of very pure fixed alkali, dried and pulverized, with two parts of Hungarian antimony also pulverized, and melt the mixture. Mr. Geoffroy made use of a retort. When the mass is melted, it must again be pulverized, while it is still hot, and then put into, and kept in, boiling hot water for an hour or two; after which the liquor, now become saline and antimoneal, must be filtered into another vessel filled with boiling water. Every ounce of antimony treated in this manner yields, by thrice boiling the melted mass, from six drams to six drams and a half of kermes; which differs from the kermes made by boiling, only in that it is not quite so soft to the touch, having in every other respect the same qualities.

As liver of sulphur is made two different ways, to wit, by boiling and by fusion, and as the kermes is nothing but a liver of sulphur in which the reguline part is dissolved; it follows that kermes may be made by fusion as well as by boiling. It is necessary to pulverize the melted mass, and to steep it in boiling-hot water for an hour or two, that the water may dissolve and divide it sufficiently to make the kermes fine and beautiful.

With the same view, that is, to make it finer and more perfect, Mr. Geoffroy orders the water saturated with the kermes made by fusion, to be received, when filtered, in a vessel full of other boiling-hot water. He observed that when the liquor impregnated with kermes cools too fast, the kermes that precipitates is much coarser. The warm solution of kermes is diffused through the boiling-hot water into which it is filtered, and is thereby enabled to retain its heat so much the longer.

From what hath been said on the nature of kermes, it plainly appears that there must be a great resemblance between it and the golden sulphur of antimony,

antimony, obtained from the scoria, either of plain regulus of antimony, or of the liver of antimony; this golden sulphur being no other than a portion of the antimony combined with the nitre alkalized during the operation.

Yet there is a difference in the manner of precipitating these two compounds: for the kermes precipitates spontaneously, on the bare cooling of the water in which it is dissolved; whereas an acid is employed to precipitate the golden sulphur suspended in the water, with which the scoria of the plain regulus of antimony, or that of liver of antimony, hath been washed. This gives some ground to suspect that the reguline part is not so intimately united with the liver of sulphur in the kermes, as in the scorixæ from which the golden sulphur is obtained.

PROCESS X.

Regulus of Antimony dissolved in the Mineral Acids.

COMPOUND an *aqua regis* by mixing together four measures of spirit of nitre, and one measure of spirit of salt: on a sand-bath moderately heated place a matrafs, into which pour sixteen times as much of this *aqua regis* as you have regulus to dissolve. Break your regulus into little bits; and throw them successively one after another into the matrafs, observing not to add a new one till that put in before is entirely dissolved: continue this till your regulus be all used. By degrees, as the dissolution advances, the liquor will acquire a beautiful golden colour; which, however will insensibly disappear, as the white fumes that continually ascend from it evaporate.

OBSERVE.

OBSERVATIONS.

Regulus of antimony is one of those metalline substances that dissolve with the greatest difficulty. Not but that most of the acids attack and corrode it; but they do not make a clear, limpid solution thereof: they in some sort only calcine it, and this semi-metal, as fast as it dissolves, precipitates of its own accord in the form of a white magistery. In order to effect a complete dissolution thereof, it is necessary to employ an *aqua regis* compounded as directed, and in the dose prescribed in the process, which is wholly taken from Mr. Geoffroy's memoirs on antimony mentioned above.

If, instead of the regulus, small bits of crude antimony be thrown into the *aqua regis*, the acid will attack and dissolve the reguline part, and so separate it from the sulphureous part which it will not touch. When the dissolution is finished, the particles of sulphur being now become lighter, because no longer united with the metalline part, will float upon the liquor. Being collected they form a true sulphur which seems no way different from common brimstone. This operation, you see, is a sort of parting process.

The vitriolic acid, whether concentrated or much weakened with water, does not act when cold either on antimony or on its regulus. This acid only dims the splendour of the facets of the regulus; but, if one part of exceeding pure regulus of antimony be put into a retort, and four parts of clear concentrated oil of vitriol poured on it, as soon as the acid is heated it turns brown, and emits a most suffocating smell of sulphur, which encreases as the regulus is penetrated and corroded by the acid.

On raising the fire, there separates from it a matter that seems mucilaginous; and when the acid hath boiled some time, the regulus is converted

into a white saline mass, as mercury is in the preparation of turbith mineral. At the same time a little sulphur sublimes into the neck of the retort. At last all the oil of vitriol passes over into the receiver, and leaves the regulus in a white, spongy, saline mass in the retort. When the fire is out, the vessels unluted, and the receiver separated from the retort, there rises a white vapour like that of the smoking liquor of Libavius.

The saline mass left in the retort, after the operation, is found increased to near double its weight: this increased weight is owing to the acid that hath united with the regulus.

This combination of the vitriolic acid with the regulus of antimony is excessively caustic, and cannot, for that reason, be administered internally.

The purest spirit of salt hath no sensible effect either on antimony or its regulus: but if antimony be coarsely pounded, it separates therefrom, though slowly, some light, sulphureous flakes.

The action of spirit of nitre on this metallic substance is more perceptible: by little and little it attacks the plates of the antimony, which discharge a great number of air-bubbles. As the dissolution advances, the acid acquires a greenish colour inclining to blue; and if there be not too much of it, it will be almost entirely imbibed by the antimony, penetrate between its *laminae*, and exfoliate them in the direction of the needles that compose them. If there be too much of the acid, that is, if it rise above the antimony, it will destroy these plates, and reduce them to a white powder.

But when the acid is imbibed slowly, we discover between the swelled *laminae* little saline transparent crystals, that vegetate much in the same manner as those of the pyrites, in which small crystals of vitriol are frequently observed, whose figures are not very well determined. These little crystals between the antimonial plates are intermixed with yellow

yellow particles, which being carefully separated burn like common sulphur.

All these useful observations, concerning the action of the acids on antimony and its regulus, we owe likewise to Mr. Geoffroy; who advises the collecting a quantity of these little crystals in time; because they disappear soon after they are formed, being probably covered by the white powder, or magistery, which is continually produced as fast as the nitrous acid disunites and separates the needle-like fibres of the antimony.

Mr. Geoffroy observed the same sort of crystals on the regulus of antimony, when substituted for crude antimony in this experiment: but it requires a great deal of care to separate these crystals; for as soon as the air comes into contact with them they lose their transparency; and, if you wait till the regulus be in some measure converted into a magistery, they are not then to be distinguished.

In order therefore to have a good view of these crystals, the regulus must be broken to pieces; these pieces put in a glass bason, and spirit of nitre poured on them to half their height, but not to cover them. This acid penetrates them, exfoliates them in white scales; and on the surface of these scales the crystals shoot of a dead-white colour. In two or three days time these crystals vegetate and grow in the form of cauli-flowers: they must then be gathered, to prevent their being confounded in the white magistery which continues to be produced, and would not suffer them to be distinguished. If you attempt to dissolve the reguline part of antimony by an *aqua regis* compounded in different proportions, and applied in a different dose, from what is prescribed in the process, the regulus of antimony will only be calcined, as it is by the other acids, and will precipitate in the form of a white magistery as fast as it dissolves, so that no part thereof will remain united with the solvent.

The proof of this is, that, if an alkaline liquor be poured, even to the point of saturation, upon the *aqua regis* that hath thus dropt the antimony, no new precipitate will be deposited.

PROCESS XI.

Regulus of Antimony combined with the Acid of Sea-salt. Butter of Antimony. Cinabar of Antimony

PUlvorize and mix thoroughly six parts of regulus of antimony, and sixteen parts of corrosive sublimate. Put this mixture into a glass retort that hath a white short neck, and let one half of its body at least be left empty. Set it in a reverberatory furnace, and having fitted a recipient thereto, and luted the joint, make a very small fire at first, to heat it slowly. Encrease it afterwards by degrees, till you see a liquor ascend from the retort that grows thick as it cools. Keep up the fire to this degree as long as you see any of this matter come over.

When no more rises with this degree of fire, unlute your vessels, take off the receiver, and in its place substitute another filled with water. Then encrease your fire by degrees till the retort be red-hot. Some running mercury will fall into the water, which you may dry and keep for use; it being very pure.

OBSERVATIONS.

In our observations on the preceding process we took notice that the purest marine acid, in the form of a liquor, will not dissolve the reguline part of antimony. Here this very acid combined with mercury, and applied in a dry form to the regulus of antimony,

antimony, quits the mercury, with which it was united, in order to join this very regulus, as having a greater affinity therewith. This operation is a further proof of what we advanced on the subject of mercury: to wit that several metallic substances, which are not soluble by certain acids when in a fluid state, may be dissolved by those acids when most highly concentrated; as they are when combined with any other substance in a dry form, and are separated from it by the force of fire. Their efficacy is also further promoted by their being reduced, on this occasion, into subtile vapours.

The marine acid combined with the reguline part of antimony doth not form a hard, solid compound; but a kind of soft substance, that melts in a very gentle heat, and also becomes fixed by the least cold, much in the same manner as butter; and from this property it hath its name.

Soon after mixing the regulus with the corrosive sublimate, the matter sometimes, grows considerably hot: this is occasioned by the marine acid's beginning to act on the reguline part, and to desert its mercury.

The butter of antimony rises with a very moderate heat; because the acid of sea-salt hath the property of volatilizing, and carrying up along with it, the metallic substances with which it is combined: and for this reason a very gentle heat only is required at the beginning of the operation.

It is absolutely necessary that the neck of the retort be wide and short; for otherwise if the butter of antimony should fix and be accumulated therein, it might stop up the passage entirely, and occasion the bursting of the vessels. By this operation we obtain eight parts and three quarters of fine butter of antimony, and ten parts of running mercury; there being left in the retort one part and a half of a rarified matter, black, white, and red. This is probably

probably the most earthy and most impure part of the regulus of antimony.

It is of the utmost consequence to the operator that he avoid with the greatest care the vapours that issue from the vessels, because they are extremely noxious, and may occasion mortal disorders. The butter of antimony is a most viviolent corrosive and caustic.

When all the butter is risen, the receiver is shifted in order to receive the mercury; which, being disengaged from the acid that gave it a saline form, appears in its natural form of quick silver: but it requires a much greater degree of heat than the butter of antimony to raise it by distillation.

If crude antimony, instead of regulus of antimony, be mixed with corrosive sublimate, a butter of antimony will be obtained in the same manner; but, instead of having a running mercury after the butter, you will find a cinabar sublimed into the neck and upper concavity of the retort.

The reason of this difference is easily conceived: for, when the regulus is used, the mercury being deserted by its acids finds no other substance to unite with, and so arises in the form of quick-silver; but when crude antimony is employed instead of its regulus, as the reguline part thereof cannot combine with the acid without quitting its sulphur, so this sulphur, being at liberty, unites with the mercury, which is so likewise, and therewith forms a cinabar; which from its origin is named *cinabar of antimony*. When you intend to make both butter and cinabar of antimony at the same time, six parts of antimony must be mixed with eight of corrosive sublimate; and care must be taken, while the butter is coming over, to warm the neck of the retort by holding some live coals near it, with the precautions necessary to avoid breaking it. This warmth makes the butter melt and run into the receiver; whereas, being thicker and of much denser

denser consistence than that made with the regulus, it would other wise gather in the neck of the retort, choak it entirely, and burst the vessel.

When the butter is drawn from crude antimony, more circumspection is necessary to make it of a beautiful white colour, than when it is obtained from the regulus: for, if the fire be too strong during the distillation, or if the receiver be not soon enough separated from the neck of the retort, certain red sulphureous vapours, the fore-runners of the cinabar, will at last ascend, and mixing with the butter give it a brown colour.

In order to restore its beauty it must be put into a clean retort, and rectified by distilling it over again with a gentle sand-heat. By this rectification the butter of antimony becomes more fluid; and by re-distilling it a second time you may give it the thinness and fluidity of an oil.

After the operation there will be found in the receiver three parts and three quarters of butter of antimony, and some small chrystals adhering to its inside, in the form of sprigs. When you break the retort there exhales from it a sulphureous odour; and you will find it in seven parts of cinabar of antimony, the greatest part of which is usually in compact glebes, that are heavy, smooth, shining, blackish throughout most of the mass, but in some places red: another part thereof appears in shining needles, and the rest in powder.

When all the butter of antimony is come over, and you begin to see the red vapours that predict the approaching ascent of the cinabar, the receiver containing the butter must be removed, lest the colour of the butter should be spoiled by those sulphureous vapours. Another receiver is usually fitted on, without luting; in which a small quantity of running mercury is sometimes found, when the operation is finished.

There remains, at the bottom of the retort, a fixed,

fixed, shining, chrystalline, black mass, which may be reduced to a regulus by the common method.

Butter of antimony may also be obtained from a mixture of antimony with any of the other preparations of mercury in which the acid of sea-salt is an ingredient; such as sweet sublimate, the mercurial panacea, and white precipitate: but as none of these combinations contain so great a proportion of that acid as is in the corrosive sublimate, the butter obtained by their means is far from being so caustic and so fiery as that which rises from a mixture of antimony, or its regulus, with corrosive sublimate.

Silver precipitated by the acid of sea salt, and ready to be melted into a *luna cornea*, being mixed with powdered regulus of antimony yields likewise a butter of antimony.

If you propose to make it by this means, you must mingle one part of the regulus of antimony in powder with two parts of the precipitate; put this mixture into a glass retort of such a size that it may fill but one half thereof; set it in a furnace; apply a receiver; begin with a gentle heat, which will make a clear liquor come over; and then increase your fire by degrees. White vapours will rise and condense into a liquid butter; and in the mean time there will be a slight ebullition in the receiver, attended with a little heat. Continue the fire till nothing more will come over; then let your vessels cool and unlute them.

You will find in the receiver an oil or butter of antimony, partly fluid and partly congealed, somewhat inclining to yellow, weighing an eighth part more than the regulus of antimony made use of.

The inside of the retort will be carpeted over with small white flowers, of a brilliant silver colour, and an acid taste; and in the bottom of the
retort

retort will be found a hard, compact, ponderous mass, difficult to break, yet falling of itself to a powder; its colour externally grey, white, and blueish; internally black, and shining much like regulus of antimony; having a saltish taste on its surface, and weighing about a sixteenth less than the precipitate of silver employed in the operation.

This experiment demonstrates that the acid of sea-salt hath a greater affinity with regulus of antimony than with silver.

The butter of antimony prepared by this method is somewhat less caustic than that made with corrosive sublimate. It is called the *lunar butter of antimony*.

The effervescence that arises in the receiver is remarkable. Probably the acid of sea-salt, though reduced into vapours when it ascends out of the retort, is not yet perfectly combined with the reguline part of the antimony, which it nevertheless carries over with it, and the union is completed in the receiver; which occasions the effervescence observed.

The little white silvery flowers, adhering to the inside of the retort, are flowers of regulus of antimony, which sublime towards the end of the distillation.

The compact mass, found at the bottom of the retort, is no other than the silver separated from its acid, and combined with a portion of the regulus of antimony. The colours and the saltish taste of its surface are occasioned by a remainder of the marine acid. The silver is rendered brittle and easier by the union it hath contracted with some of the regulus of antimony.

It is easy to purify it, and restore its ductility, by separating it from the regulus of antimony. There are several ways of doing this: one of the most expeditious is to flux it with nitre, which burns and converts

converts to a calx the semi-metal with which the silver is adulterated.

PROCESS XII.

Butter of antimony decomposed by means of water only. The Pulvis Algaroth, or Mercurius Vita. The Philosophic Spirit of Vitriol.

MELT with a gentle heat as much butter of antimony as you please. When it is melted, pour it into a large quantity of warm water. The water will immediately grow turbid, but whitish, and let fall a great quantity of white powder. When all the precipitate is settled, decant the water: pour on fresh warm water; and having thus edulcorated it by several ablutions, dry it, and you have the *Pulvis Algaroth*, or *Mercurius Vita*.

OBSERVATIONS.

In the preceding processes we observed that the marine acid will not dissolve the reguline part of antimony, unless it be very highly concentrated and more so than it can possibly be while in the form of a liquor. Of this the experiment before us is a further proof. Whilst the marine acid is perfectly dephlegmated, as it is in corrosive sublimate and butter of antimony, it remains combined with the reguline part of antimony; but if this combination be dissolved in water, the moment the acid is weakened by the interposition of the particles of water, it becomes incapable of continuing united with the semi-metal which it had before dissolved; deserts it, and lets it fall in the form of white powder.

The *Pulvis Algaroth* is therefore no other than

the reguline part of antimony, attenuated and divided by the union it had contracted with the acid of sea-salt, and afterwards separated from that acid by the intervention of water alone. The proof is, that this powder retains none of the properties of the butter of antimony: it is neither so fusible nor so volatile; on the contrary, it is capable of sustaining a very strong degree of fire, without subliming and without melting: It may be reduced to a regulus: it hath not now the same caustic nature: it is only an emetic; which however is extremely violent, and on that account is never prescribed by any prudent physician.

Another proof, that the marine acid is separated from the regulus of antimony in the precipitation of the *Pulvis Algaroth*, is that the water in which this precipitation is made becomes acid, or a sort of weak spirit of salt. If it be evaporated, and concentrated by distillation, a very strong acid liquor may be obtained from it. This acid goes, very improperly, by the name of the *philosophic spirit of vitriol*; for it is rather a spirit of salt.

The *Pulvis Algaroth*, made with butter of antimony procured from the regulus, is whiter than that made with butter of antimony procured from crude antimony; probably because the latter always retains some sulphureous particles.

Butter of antimony exposed to the air attracts the moisture thereof, and partly runs into a liquor; but, as fast as this liquor is produced, it deposits a white sediment, which is an actual *Pulvis Algaroth*. This also is very agreeable to what we advanced touching the decomposition of butter of antimony by the addition of water. The butter attracts the moisture of the air, because the acid it contains is exceedingly concentrated; and this moisture produces the same effect as water purposefully added.

P R O-

PROCESS XIII.

Bezoar Mineral. The Bezoartic Spirit of Nitre.

MELT butter of antimony over warm ashes, and put it into a phial or matrafs. Gradually pour on it good spirit of nitre, till the matter be entirely dissolved. This usually requires as much spirit of nitre as there is butter of antimony. During the dissolution fumes will rise, which must be carefully avoided. Pour your solution, which will be clear and of a redish colour, into a glass cucurbit, or a pan of stone-ware; set it in a sand bath, and evaporate to dryness with a moderate heat. There will be left a white mass, weighing a fourth part less than the whole quantity used, both of the butter and the spirit of nitre. Let it cool, and again pour on it as much spirit of nitre as you used the first time. Place the vessel again in the sand-bath, and evaporate the moisture as before. You will have a white mass that hath neither gained nor lost in weight. On this pour, for the third time, the same quantity of spirit of nitre as you did the first time. Again evaporate the moisture to perfect dryness: then increase your fire, and calcine the matter for half an hour. You will have left a dry, friable, light, white matter, of an agreeable acid taste; which will fall into a coarse powder, and must be kept in a phial carefully stoppt. This is *Bezoar Mineral*: it is neither caustic nor emetic, and has only a sudorific virtue. It obtained the name it bears, because, like the animal bezoar, it was imagined to have the property of resisting poison.

OBSERVE

OBSERVATIONS.

It is not surprizing that the nitrous acid poured on butter of antimony should dissolve it, and unite with it: for with the marine acid, which makes a part of this combination, it forms an *aqua regis*, which we know is the true solvent of the reguline part of antimony. But in this dissolution, and the changes it produces, there are some things very remarkable and worthy of attention. 1. The nitrous acid, by uniting with the butter of antimony, deprives it of its property of rising with a very gentle heat, and makes it much more fixed: it can now be dried, and suffer all its moisture to be evaporated; which is not to be done with pure butter of antimony: for that, being exposed to a certain degree of heat, instead of letting go its moisture and remaining dry, rises wholly, without the least appearance of any separation of parts.

2. The butter of antimony, which before its combination with the nitrous acid is a most violent caustic and corrosive, becomes so mild after it, that it may not only be taken internally without danger, but hath scarce any sensible operation.

The following considerations will lead us to a reasonable explanation of these phenomena. 1. The nitrous acid, when combined with metallic substances, doth not communicate to them the same volatility as they acquire from the marine acid. Hence it follows that, if the nitrous acid be added to any combination of a metallic substance with the marine acid, this new compound will be rendered less volatile, and consequently more able, without rising in vapours, to bear a degree of heat sufficient to carry off part of its acid. This is the case with butter of antimony, after spirit of nitre

is mixed with it : especially considering, 2. That the nitrous acid cannot unite with the reguline part of the butter of antimony without weakening the connection between it and the marine acid ; whence it follows that the combination of the nitrous acid further facilitates the separation of the marine acid from the regulus. Now as soon as the marine acid quits the reguline part, that part becomes more fixed, and consequently more capable of enduring the degree of heat requisite to discharge all the adhering acid ; and not only the marine, but even the nitrous also. It is not therefore surprizing that, after the antimony which remains combined with the nitrous acid is dried, it should not possess that corrosive power which it derives only from the acids wherewith it is armed. In order to free it more perfectly from all acid, we order the fire to be increased after the third desiccation ; and the remainder of the butter of antimony to be calcined for a full half-hour longer

That the marine acid is separated from the reguline part of the butter of antimony, by the desiccations it undergoes in converting it into bezoar, is proved by this, that, when these desiccations are performed in close vessels, the liquor drawn off is a true *aqua regis*, known by the name of the *bezoartic spirit of nitre*.

It remains to be considered why the bezoar mineral, though freed from all acid, is not emetic, while the *pulvis algaroth*, which is likewise the reguline part of the butter of antimony deprived of its acid, is such a violent emetic, and even to be dreaded for its remaining causticity.

In order to discover the reason of this difference it is proper to observe that, when we say bezoar mineral and the *pulvis algaroth* contain no acid, we must not be understood in too strict a sense : on the contrary, there is reason to think that a certain quantity of acid still remains in each of them

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which however is scarce worth notice, in comparison of the quantity each contained at first. This being allowed, it will not be hard to find the difference between these two preparations of antimony. The *pulvis algaroth* is deprived of its acid by the addition of water alone, which only carries off all the loose acid it can take up, without making any change in the nature of that which continues in combination with the reguline part. Now, as the marine acid is not intimately united with the reguline part in butter of antimony; as it still retains some of its properties, such as attracting the moisture of the air, giving manifest tokens of its acid nature, &c. and as the corrosive quality of this compound depends on this last in particular; the small portion of acid left in the *pulvis algaroth* will in some degree preserve its former character: and hence comes the effect of this powder, which still retains a little of the corrosive quality that belonged to the butter of antimony.

But this is not the case with the small remainder of acid, which possibly still continues united with the bezoar mineral prepared as here directed. This compound hath been exposed to a fire sufficient, not only to dry it, but even to calcine it. Now fire is capable of producing great changes in the texture of bodies. It must have forced off from the bezoar all the acid that was not intimately combined with it; and that part which it could not drive off, because of its obstinate adhesion, it must have further united and combined more closely with the metallic earth: for we see that fire greatly promotes the action of solvents on the matters with which they are united.

With regard to the properly emetic quality of the *pulvis algaroth*, it cannot be imputed to the combination of any acid with that powder; since we see that the most powerfully emetic preparations of antimony, viz. its regulus and glass, contain no

acid : it must therefore be attributed to some cause different from that on which its corrosive quality depends. This cause we shall easily find by attending to the different manners in which the marine acid, when alone and in *aqua regia*, operates on the reguline part of antimony.

The marine acid alone dissolves the regulus of antimony, but with great difficulty ; nor doth it effect a compleat dissolution thereof, as is evident from what hath been already said : whereas the marine acid, combined with the nitrous acid, and therewith forming an *aqua regis*, as in the preparation of bezoar, dissolves the reguline part of antimony completely and radically. Now, it is certain that, the more efficaciously acids operate on metallic substances, the more of their phlogiston do they destroy ; and we cannot but recollect that the preparations of antimony are so much the less emetic the less phlogiston they contain, or the further they recede from the nature of a regulus, and the nearer they approach to that of diaphoretic antimony ; consequently it is plain how bezoar mineral, which is a sort of calx of antimony entirely deprived of its phlogiston by the intimate dissolution thereof made by the acids of the *aqua regis*, may be in no degree emetic ; while the *pulvis algdrot*, being a true regulus of antimony, on which the marine acid hath operated but very superficially, and which still contains a great deal of phlogiston, is a most violent emetic.

PROCESS XIV.

Flowers of Antimony.

TAKE an unglazed earthen pot, having an aperture in its side, with a stopple to shut it close. Set this pot in a furnace, the cavity whereof

it may fit as exactly as possible; and fill up with lute the space, if any, left between the vessel and the furnace. Over this vessel fix three aludels, with a blind-head at the top; and light a fire in the furnace under the pot.

When the bottom of the pot is thoroughly red, throw into the lateral aperture a small spoon-full of powdered antimony. Stir the matter immediately with an iron spatula made a little bending, in order to spread it over the bottom of the vessel, and then stop the hole. The flowers will rise and adhere to the insides of the aludels. Keep up the fire so that the bottom of the pot may always continue red; and, when nothing more sublimes, put in a like quantity of antimony, and operate as before. In this manner go on subliming your antimony, till you have as many flowers as you want. Then let the fire go out; and when the vessels are cold unlute them. You will find flowers adhering all round the insides of the aludels and the head, which you may collect with a feather.

OBSERVATIONS.

Antimony is a volatile mineral, capable of being sublimed into flowers; but this cannot be effected without occasioning a notable change in its parts. The reguline and the sulphureous parts are not united so intimately, or in the same proportion, in the flowers as in the antimony itself; and accordingly we find these flowers have a strong emetic quality, which antimony hath not. They are of divers colours; which probably arises from their containing more or less sulphur. Three or four aludels are placed one over another, not only with a view to provide a greater surface to which the flowery may adhere, but also to give them room enough to circulate, without which they might burst the vessels.

If you introduce the nose of a pair of bellows into the pot that contains the antimony, and blow upon it, the sublimation of the flowers will be much sooner effected. This is a general rule with regard to all matters that are to be sublimed or evaporated; the reason of which we have already given.

It is proper that no interval be left between the furnace and the pot containing the antimony, lest the heat should be thereby communicated to the aludels, on which the flowers fasten best when they are cold.

After the operation there remains, at the bottom of the pot, a portion of antimony half calcined; which being pulverized, and thoroughly calcined till it emit no fume, may be employed to make the glass of antimony.

PROCESS XV.

Regulus of Antimony converted into Flowers.

PULVERIZE your regulus of antimony: put the powder into an unglazed earthen pot: three or four fingers breadth above the powder, fit into the pot a little cover, made of the same earth, and having a small hole in its middle, so that it may with ease be placed in the pot, and taken out when there is occasion: cover the mouth of the pot with a common lid; set it in a furnace, and kindle a fire under it sufficient to make the bottom of the pot-red, and to melt the regulus. When it hath been thus kept in fusion for about an hour, let the fire go out, and the whole cool. Then remove the two covers. You will find adhering to the surface of the regulus, which will be in a mass at the bottom of the pot, white flowers resembling snow, intermixed with beautiful, brilliant, silver-coloured needles. Take them out, and you will find them make

make about one part in sixty-two of the whole regulus employed.

Put the covers again in their places, and proceed in the same manner as before: when the vessels are cold you will find half as many more flowers as you got the first time.

Proceed thus till you have converted all your regulus into flowers. This will require a considerable number of sublimations, which, as you advance, will always yield you a greater portion of flowers; respect, however, being had to the quantity of regulus remaining in the pot.

OBSERVATIONS.

We must here repeat what we said just before, in our observations on the preceding process; viz. that regulus of antimony is capable of being wholly elevated and sublimed by the action of fire; but that it must at the same time undergo a considerable change and alteration. These flowers of regulus of antimony are very different from every other antimoneal preparation. They resemble the pearly matter in this, that they cannot be reduced to a regulus by any means whatever: but they differ from it, 1. in that they are not fixed; for, when melted by fire, they fly wholly away in vapours: 2. in that they are capable of being dissolved by *aqua regis*, much in the same manner as the regulus; whereas the pearly matter is known to be indissoluble by any acid.

As soon as regulus of antimony is in fusion, it begins to sublime into flowers; so that it is needless to apply a greater degree of heat than is just sufficient to melt it.

A pan of some width is preferable to a crucible for this operation: because the upper surface of the regulus melted therein is larger, and, the larger that

that surface is, the more considerable is the quantity sublimed from it.

The two covers which are applied within and over the pot are designed to check, as much as possible, the dissipation of the melted regulus; yet without absolutely excluding the free access of the air, the concourse of which is useful in all metallic sublimations. Notwithstanding these precautions, it is impossible to prevent the escape of some of the regulus, in vapours that cannot be confined. Somewhat less than three fourths of the regulus made use of is nearly the yield in flowers: the rest evaporates through the interstices left by the covers which must not be luted for the reason just assigned.



CHAP. II.

Of BISMUTH.

PROCESS I.

To extract Bismuth from its Ore.

BREAK the ore of bismuth into small pieces, and therewith fill a crucible either of earth or iron. Set the crucible in a furnace, and light such a fire that the bits of ore may become moderately red. Stir the ore from time to time, and, if you perceive it crackle and fly, keep the crucible covered. At the bottom you will find a button of bismuth.

OBSERVATIONS.

The extraction of bismuth from its ore requires nothing

nothing but simple fusion, without the addition of any inflammable matter, because it is naturally possessed of its metalline form. Nor does it require any flux; because it is very fusible: which allows us to melt it, and collect it in a mass, without the necessity of fusing likewise the earthy and stony matters in which it is lodged. These matters remain in their first state; and the melted bismuth descends by its gravity to the bottom of the crucible. No greater degree of heat must be applied, on this occasion, than is necessary to melt the semi-metal: for, as it is volatile, part of it would be dissipated; so that much less thereof would be obtained, if the fire were made too strong, and so much the less as another portion thereof would be converted into a calx. For the same reason, the crucible must be taken out of the furnace as soon as you perceive that all the bismuth contained in the ore is melted, and that the button doth not increase.

The ore of bismuth may also be treated like the ores of lead and tin; that is, it may be reduced into a fine powder, mixed with the black flux, a little borax, and sea salt; put into a close crucible, and fused in a melting furnace. In that case you will find a button of regulus covered with scoria. By this method rather more bismuth is obtained; and it is best to make use of it when the ore is poor, because, in such a case, none at all would be obtained by the other process. But here care must be taken to apply at once the degree of fire necessary to melt the mixture: for, if it remain long in the fire, much bismuth will be lost, on account of the great volatility of this semi-metal, and the facility with which it turns to a calx.

Bismuth is pretty frequently found pure in its earthy and stony matrices; and when mineralized it is usually so by arsenic, which, being still more volatile, flies off in vapours while the ore is melting, provided it be but in a small quantity: if there

there be much of it, and the ore be smelted by fusing it with the black flux, the arsenic also is reduced to a regulus, unites more intimately with the bismuth, becomes a little more fixed by that union, and increases the quantity of the semi-metallic mass found after the fusion.

Though bismuth be not usually mineralized by sulphur, that is not because it is incapable of uniting therewith; for, if equal parts of bismuth and sulphur be melted together, after the fusion the bismuth will be found increased near an eighth part, and formed into a mass disposed in needles much like antimony.

When we come to treat of the ore of arsenic, we shall have occasion to say a good deal more concerning bismuth and its ore; because these minerals resemble each other very much.

Mr. Geoffroy, son of the Academician, hath shewn in a memoir read before the academy of Sciences, that there is a great resemblance between bismuth and lead. That memoir, which contains only the beginning of Mr. Geoffroy's course of experiments, proves that the author supports with dignity the glory of his name. It is there demonstrated, by a very great number of experiments, that fire produces the same effects on bismuth as on lead. This semi-metal is converted into a calx, into litharge, and into glass, as lead is; and these productions have the same properties as the preparations of lead made with the same degree of fire. Bismuth is capable of vitrifying all the imperfect metals, and of carrying them off through the pores of the crucible. So that gold and silver may be purified and cupelled by its means, as well as with lead. You may on this occasion turn to what we have said concerning lead.

P R O C E S S II.

*Bismuth dissolved by Acids. Magistery of Bismuth.
Sympathetic Ink.*

INTO a matrafs put bismuth broken into little bits: pour on it, by little and little, twice as much *aqua fortis*. This acid will attack the sem-metal briskly, and dissolve it entirely, with heat, effervescence, vapours, and puffing up. The solution will be clear and limpid.

O B S E R V A T I O N S.

Of all acids the nitrous is that which best dissolves bismuth. It is not necessary, on this occasion, to place the phial, in which the dissolution is performed, on a sand-heat, as in most other metallic dissolutions: on the contrary, care must be taken not to pour on all the *aqua fortis* at once; because it operates with so much activity that the mixture will heave up and run over the vessel.

The bare addition of water is sufficient to precipitate the solution of bismuth. If this solution be mixed with a very large proportion of water, the liquor grows turbid, appears milky, and deposits a precipitate of a very beautiful white. This is that white which the ladies use at their toilets.

Water produces this precipitation by weakening the acid; which probably is incapable of keeping the bismuth dissolved, unless it have a certain degree of strength.

If you would have a magistery of bismuth beautifully white, you must perform the dissolution with an *aqua fortis* that is not tainted with any mixture of the vitriolic acid; for this gives the precipitate a dirty white colour, inclined to grey. Several authors

thors advise the use of a solution of sea-salt, instead of pure water, for precipitating the bismuth, imagining that this salt will effect a precipitation here as it does in the cases of silver and lead. But Mr. Pott, a German chymist, who hath published a long dissertation on bismuth, pretends, on the contrary, that neither sea-salt, nor it's acid, is capable of precipitating this semi metal; and that when a precipitation takes place on mixing them with our solution, it is brought about only by means of the water in which those substances are diffused.

Bismuth may also be precipitated by the means of fixed or volatile alkalis; but the precipitate is not of so fine a white as when procured by the means of pure water only.

If a greater quantity of *aqua fortis*, than that prescribed in the process, be made use of to dissolve the bismuth, a great deal more water will also be required to precipitate the magistery; because there will be much more acid to weaken. This white ought to be well washed, in order to free it from any remainder of acidity: and it should be kept in a bottle well stopped; because the access of the air makes it turn brown, and if any of the acid be left it will turn it yellow.

A solution of bismuth prepared with the proper quantity of *aqua fortis*, that is, with two parts of the acid to one of the semi-metal, concretes into little chrystals almost as soon as made.

Aqua fortis not only acts on bismuth when separated from it's ore, and reduced to a regulus, but attacks it even in its ore, and likewise dissolves at the same time some portion of the ore itself. With this solution of the ore of bismuth Mr. Hellot makes a very curious sympathetic ink, differing from all that were known before.

Mr. Hellot prepares the liquor in the following manner: "He bruises the ore of bismuth to a coarse powder. On two ounces of this pow-

der he pours a mixture of five ounces of common water with five ounces of *aqua fortis*. He does not heat the vessel till the first ebullitions are over. He then sets it in a gentle sand-heat, and lets it digest there till he sees no more air-bubbles rise. When none appear in this heat, he increases it so as to make the solvent boil slightly for a full quarter of an hour. It takes up a tincture nearly of the colour of brown beer. The ore that gives the *aqua fortis* this colour is the best. He then lets the solution cool, laying the matrafs on its side, that he may decant the liquor more conveniently when all is precipitated that is not taken up by the solvent.

" The second vessel, into which the liquor is first decanted, he also lays declining, that a new precipitation of the undissolved matters may be obtained; after which he pours the liquor into a third vessel. This liquor must not be filtered, if you would have the rest of the process succeed perfectly; because the *aqua fortis* would dissolve some of the paper, and that would spoil the colour of your liquor,

" When this solution, which Mr. Hellot calls the *impregnation*, is thoroughly clarified by being decanted three or four times, he puts it into a glass basin with two ounces of very pure sea-salt. The fine white salt made by the sun succeeded best with Mr. Hellot. If that cannot be had, common bay-salt, purified by solution, filtration, and crystallization, may be used instead of it. But as it is rare to meet with any of the sort that is not a little tainted with iron, the white bay-salt is to be preferred. The glass basin he sets in a gentle sand-heat, and keeps it there till the mixture be reduced by evaporation to an almost dry saline mass.

" If you desire to save the *aqua regis*, the impregnation must be put into a retort, and distilled.

" led with the gentle heat of a sand bath. But
 " there is an inconvenience, as Mr. Hellot observes
 " in employing a retort; which is, that, as the
 " line mass cannot be stirred while it coagulates in
 " the retort, it is reduced to a compact cake of co-
 " loured salt, which presents but one single sur-
 " face to the water in which it must be dissolved
 " so that the dissolution thereof takes up some
 " times no less than five or six days. In the basin
 " on the contrary, the saline mass is easily brought
 " to a granulated salt, by stirring it with a glass
 " rod; and, when thus granulated, it has a great
 " deal more surface; it dissolves more easily, and
 " yields its tincture to water in four hours time
 " indeed one is more exposed to the vapours of
 " the solvent, which would be dangerous, if the
 " operation were to be often performed, without
 " proper precautions.

" When the basin, or little vessel, containing
 " the mixture of the impregnation and sea-salt
 " heated, the liquor, which was of an orange co-
 " loured red; becomes a crimson red; and, when
 " all the phlegm of the solvent is evaporated, it ac-
 " quires a beautiful emerald colour. By degrees
 " thickens, and acquires the colour of a mass
 " verdegris. It must then be carefully stirred with
 " the glass rod, in order to granulate the salt
 " which must not be kept over the fire till it is
 " perfectly dry; because you run a risk of losing
 " irrevocably the colour you are seeking. You
 " may be sure you have lost it, if by too much
 " heat the salt that was of a green colour becomes
 " of a dirty yellow. If it be once brought to this
 " state, it will continue without changing when
 " cold: but if care be taken to remove it from the
 " fire while it is still green you will see it gradually
 " grow pale, and become of a beautiful rosy
 " colour as it cools.

" Mr. Hellot removes it from this vessel, and

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throws it into another containing distilled rain water: and this second vessel he keeps in gentle digestion till he observes that the powder which falls to the bottom is perfectly white. If, after three or four hours digesting, this powder still continues tinged with rose colour, it is a proof that water enough was not added to dissolve all the salt impregnated with the tincture of the solution. In this case, the first tinged liquor must be poured off, and fresh water added, in proportion to the quantity of tinged salt, that is supposed to remain mixed with the precipitate.

“When the ore is pure, and doth not contain a great deal of fusible stone, commonly called *fluor* or *quartz*, an ounce of it generally yields tincture enough for eight or nine ounces of water, and the liquor is of a beautiful colour, like that of the lilach or pipe-tree blossom. In order to prove the effect of this tincture, you must write with this lilach-coloured liquor on good well gummed paper, that does not sink: or you may use it to shade the leaves of some tree or plant, having first drawn the outlines thereof lightly, with china-ink or with a black-lead pencil. Let this coloured drawing, or writing, dry in a warm air. You will perceive no colour while it is cold; but, if it be gently warmed before the fire, you will see the writing, or the drawing, gradually acquire a blue or greenish-blue colour, which is visible as long as the paper continues a little warm, and disappears entirely when it cools.”

The singularity of this sympathetic ink consists in its property of disappearing entirely and becoming invisible, though it be not touched with anything whatever: and this distinguishes it from all others; which, when once rendered visible by the application of proper means, do not again disappear

pear, or at least not without touching the stroke on the paper with some other liquor.

Mr. Hellot made a vast variety of experiments on this subject, and gave his sympathetic ink successively the properties of all others that are known.

It follows from Mr. Hellot's experiments that it is the acid of sea-salt which makes this saline magma of a green colour while it is hot; that without this acid the saline matter continues red; and that the solution of bismuth-ore in *aqua fortis* may therefore serve as a touchstone, to discover whether or no any unknown salt under examination contains sea-salt, or a portion of the marine acid.

He also proves, in the memoirs he hath given in on this subject, that the nitrous acid is the true solvent of those ores of bismuth which contain moreover smalt and arsenic. That acid dissolves all the metallic and colouring matters contained in those ores, sparing nothing but the sulphureous and arsenical portion, the greatest part of which remains precipitated; and from this colouring matter the sympathetic ink derives its virtue.

Under the head of arsenic we shall speak more amply of this matter in cobalt, or the ore of arsenic, that gives a blue colour to the sand with which it is vitrified.

The vitriolic acid doth not, properly speaking, dissolve bismuth. If to one part and a half of this semi-metal you add one part of oil of vitriol; distill the whole to dryness; and then lixiviate with water what remains in the retort; the liquor you obtain by this means will be of a redish yellow colour, but will let nothing fall when mixed with an alkali: and this shews that the vitriolic acid acts only upon the inflammable part of bismuth, and doth not dissolve its metallic earth.

It dissolves the ore of Bismuth more perceptibly than bismuth itself; because the ore contains, be-

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sides the reguline part, an arsenical matter, and a coloured matter, over which perhaps it hath more power.

The acid of sea-salt attacks and dissolves bismuth in some small measure, but slowly and with difficulty.* That this acid dissolves a portion of our semi-metal may be proved, by mixing a fixed or volatile alkali with spirit of salt in which bismuth hath lain some time digesting; for then a precipitate falls.

But, though the marine acid be capable of dissolving bismuth, it doth not follow that it hath a greater affinity than the nitrous acid with this metallic substance; as some chymists have thought; who imagined that, in the precipitation of the magnifery of bismuth by a solution of sea-salt, the acid of that salt quits its basis to unite with the bismuth which it precipitates, as is the case in the precipitations of lead and of silver by the same salt, and that it forms, on this occasion, a *Bismuthum corneum*.

On this subject Mr. Pott observed, 1. that when only a small quantity of the solution of sea-salt is mixed with the solution of bismuth in the nitrous acid, no precipitate is formed: now it is certain that when the smallest quantity whatever of sea-salt is mixed with the solution either of lead or of silver, a precipitate is immediately deposited, in a quantity proportioned to that of the salt used.

2. Mr. Pott, having examined the precipitate of bismuth thrown down by a solution of sea-salt, found it not to have the properties of a metallic substance rendered horny: on the contrary, that precipitate being exposed to a very violent fire appeared refractory, and could not be melted.

M^r Newnan shews they may be united by distilling the Bismuth with the mercuric sublimation.



C H A P. III.

Of Z I N C.

P R O C E S S I.

To extract Zinc from its ore, or calamine.

TAKE eight parts of calamine reduced to a powder ; mix this powder accurately with one part of fine charcoal-dust, previously calcined in a crucible to free it from all moisture : put this mixture into a stone retort coated with lute, leaving a third part of it empty ; set your retort in a reverberatory furnace, capable of giving a very fierce heat. To the retort apply a receiver, with a little water in it. Kindle the fire, and raise it by degrees till the heat be strong enough to melt copper. With this degree of fire the zinc being metallized will separate from the mixture, and sublime into the neck of the retort, in the form of metallic drops. Break the retort when it is cold, and collect the zinc.

O B S E R V A T I O N S.

The process here given for smelting zinc out of calamine is taken from the memoirs of the academy of sciences at Berlin. The author of it is Mr. Marggraff, a skilful chymist, whom we have already had occasion to mention under the article of Phosphorus.

Till this process was published, we knew no method

method of obtaining pure zinc directly from the *lapis calaminaris*.

Most of the zinc we have comes from an ore of difficult fusion that is worked at Goslar, and yields, at one and the same time, lead, zinc, and another metallic matter called *cadmia fornacum*, which also contains much zinc, as we shall afterwards see.

The furnace used for smelting this ore is closed on its fore-side with thin plates or tables of stone, not above an inch thick. This stone is greyish, and bears a violent fire.

In this furnace the ore is melted amidst charcoal, by the help of bellows. Each melting takes twelve hours, during which time the zinc flowing with the lead is resolved into flowers and vapours, great part of which adheres to the sides of the furnace in the form of a very hard crust of earth. The workmen take care to remove this crust from time to time; for it would otherwise grow so thick at last as to lessen the cavity of the furnace very considerably.

There adheres moreover to the fore-part of the furnace, which is formed, as we said before, of thin plates of stone, a metallic matter, which is the zinc, and is carefully collected at the end of each melting, by removing from this part all the live coals. A quantity of small-coal is laid unlighted at the bottom; and on this small coal, by striking the stone plates gently with a hammer, the zinc is made to fall out of the other matter, known by the Latin name of *cadmia fornacum*, among which it appears fixed in a radiated form. To this other matter we may probably enough give the name of *furnace-calamine*. The zinc falls in the form of a melted metal, all on fire, and in a bright flame. It would soon be entirely burnt and reduced to flowers, as we shall see, if it were not extinguished, and easily cooled and fixed, by being hid under the unlighted

unlighted small-coal placed below on purpose to receive it.

The zinc adheres to the fore-part of the furnace preferably to any other, because that being the thinnest is therefore the coolest: and, in order further to promote its fixing on this part, they take care to keep the thin stone plates cool during the operation, by throwing water on them.

Hence it appears that zinc is not extracted from its ore by fusion and the precipitation of a regulus, like other metallic substances. This is owing to the great volatility of our semimetal, which cannot, without subliming, bear the degree of fire necessary to melt its ore. It is at the same time so combustible, that a great part of it rises in flowers which have not the metalline form.

Mr. Marggraff provides against these inconveniences by working the ore of zinc in close vessels. By this means he prevents the zinc from taking fire, and being converted into flowers; so that it sublimes in its metalline form. The water in the recipient serves to receive and cool the drops of zinc that may be forced quite over the helm. As the operation requires a most violent fire, these drops must needs issue exceeding hot, and, without this precaution, break the recipient.

Mr. Marggraff by the same process extracted zinc out of the furnace-calamine procured from ores containing zinc; from tutty, which is a sort of furnace-calamine; from the flowers and from the calx of zinc; and from the precipitate of white vitriol; all of them matters known to be zinc, that wanted nothing but the phlogiston to give it a semi-metalline form, and from which nevertheless no body could ever before him procure any zinc.

Mr. Marggraff observes, that the zinc obtained by his process bears being flated under the hammer into pretty thin plates; which the common zinc will

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will not do. The cause of this probably is, that the zinc obtained by his method is more intimately combined with the phlogiston, and contains a greater quantity thereof, than that which is procured in the ordinary way.

PROCESS II.

To sublime Zinc into Flowers.

TAKE a very deep, large crucible: place it in a furnace, so that it may stand inclining in an angle of forty-five degrees nearly. Throw some zinc into it, and kindle a fire in the furnace somewhat stronger than would be necessary to keep lead in fusion. The zinc will melt. Stir it with an iron wire, and there will appear on its surface a very bright white flame: two inches above this flame a thick smoak will be formed, and with this smoke exceeding white flowers will rise, and remain some time adhering to the sides of the crucible, in the form of a very fine light down. When the flame slackens, stir your melted matter again with the iron wire: you will see the flame renewed, and the flowers begin again to appear in greater abundance. Go on thus till you observe that the matter will not flame, nor any more flowers rise.

OBSERVATIONS.

Zinc takes fire very easily as soon as it is affected by a certain degree of heat; which proves that in the composition of this semi-metal there is very much phlogiston, united but slightly with its metallic earth. The flowers into which zinc resolves, during its combustion, are of a perfectly singular nature, and differ greatly from all the other

ther productions obtainable out of metallic substances.

They may be considered as the very calx of zinc, or its metallic earth robbed of its phlogiston, and sublimed during the combustion of this semi-metal, being probably carried up by the phlogiston in flying off. For these flowers, when once sublimed, are afterwards exceedingly fixed: they sustain the greatest violence of fire without rising, and are converted by it into a sort of glass.

None of the methods hitherto employed, for restoring to the flowers of zinc their metalline form, have ever succeeded, when treated like other metalline calxes in a crucible, with every kind of inflammable matter, and different sorts of reducing fluxes, they never can be re-metallized: they only melt with the flux, and produce a kind of glass.

Mr. Marggraff indeed, as mentioned before, obtained zinc from these flowers, by treating them as he did calamine in a retort with charcoal dust: but as the flowers often carry up with them little particles of undecomposed zinc, there still remains some doubt concerning the reduction of these flowers, even by this method.

If the crucible, into which you put the zinc to be converted into flowers, instead of being left open, as directed, be covered with another crucible inverted, the two vessels luted together, placed in a melting furnace, and a strong fire immediately kindled and kept up for about half an hour; you will find, when the vessels are cold, that all the zinc hath left the lower crucible, and is sublimed into the upper one, in its metalline form, without suffering any decomposition. This experiment proves that zinc, to be converted into flowers, must necessarily be set on fire and burnt. As it cannot burn in close vessels, any more than other combustible bodies, and as it is volatile, it sublimes without suffering any decomposition. *Regulus of antimony*

timony and bismuth may be sublimed in the same manner ; but not so easily as zinc, which is still more volatile than those other semi-metals.

It is necessary to stir the zinc in fusion from time to time with an iron wire, when you intend to convert it into flowers ; for there forms on its surface a grey crust that obstructs its deflagration, and beneath which it is gradually converted into a clotted calx. In order, therefore, to promote the rising of the flowers, care must be taken to break this crust, as oft as it begins to form. On this there immediately appears a very bright white flame : two inches above the flame is seen a thick smoke, and with this smoke very white flowers rise, that continue some time adhering to the inside of the crucible, in the form of a fine down.

M. Malouin, who, in sundry memoirs on zinc, hath endeavoured to discover what resemblance there is between this semi-metal and tin, tried to calcine zinc in the same manner as tin ; but found it somewhat more difficult. Zinc, while it is not in fusion, doth not calcine ; but it begins to turn to a calx the moment it begins to melt. M. Malouin, having repeated the fusion of zinc a great number of times, by that means collected at last a quantity of the calx of this semi-metal, resembling other metalline calxes. This calx of Zinc he melted in a crucible with animal fat ; whereby the calx was remetallized, and reduced to zinc. There is great reason to believe that the calx of zinc made by this method is not so much burnt as the flowers, and that it still contains a portion of phlogiston.

P R O C E S S I I I .

To combine Zinc with Copper. Brass. Prince's Metal, &c.

POUND one part and a half of calamine, and an equal quantity of charcoal : mingle these two powders together, and moisten them with a little water. Put this mixture into a large crucible, or some other earthen vessel that will bear a melting heat. Amongst and over this mixture put one part of very pure copper in thin plates, and then put fresh charcoal-dust over all : cover the crucible ; set it in a melting furnace ; put coals all round it, and let them kindle gradually. Raise the fire so as to make the crucible very red-hot. When you observe that the flame hath acquired a purple or blueish-green colour, uncover the crucible, and dip into it an iron wire, to examine whether or no the copper be in fusion under the charcoal dust. If you find it is, moderate the force of the fire a little, and let your crucible remain in the furnace for a few minutes. Then take it out and let it cool : you will find your copper of a gold colour, increased in weight a fourth, or perhaps a third part, and yet very malleable.

O B S E R V A T I O N S .

The *lapis calaminaris* is not the only substance with which copper may be converted into brass : all other ores containing zinc, the furnace-calamine that sublimes where such ores are worked, tutty, zinc in substance, may be substituted for it, and, like it, will make very fine brass ; but, in order to succeed, sundry precautions are necessary which we shall now lay before you.

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This process is a sort of cementation : for the calamine doth not melt ; only the zinc is converted into vapours, and then combines with the copper. On this the success of the operation partly depends, as it is the means of the copper's preserving its purity and malleability ; because the other metallic substances that may be united with the ore of zinc, or with the zinc itself, not having the same volatility, cannot be reduced to vapours. If you are apprized that the calamine, or other ore of zinc, used on this occasion, is contaminated with a mixture of any other metallic matter, you must mingle luting earth with the charcoal-dust and the matter containing the zinc ; make it into stiff paste with water ; of this make a bed at the bottom of your crucible, and ram it hard down ; lay the copper plates thereon, cover them with charcoal-dust, and then proceed as before. By this means when the copper melts it cannot fall to the bottom of the crucible, nor mix with the ore ; but is borne up by the mixture, and cannot combine with any thing but the zinc, that rises in vapours, and, passing through the lute, fixes in the copper.

Lapis calaminaris, or other ore of zinc, may also be purified before it be used for making brass ; especially if adulterated with lead ore, which is often the case. For this purpose the ore must be roasted in a fire strong enough to give a small degree of fusion to the leaden matter ; which will thereby be reduced into larger, heavier, and tougher masses. The most subtile particles are dissipated in the torrefaction, together with some of the calamine. The calamine, on the contrary, is by roasting made more tender, lighter, and much more friable. When it is in this condition, put it into a washing tray or van ; dip the tray in a vessel full of water, and bruise the matter it contains. The water will carry off the lightest powder, which is the calamine, and leave nothing at the

bottom of the tray but the heaviest substance; that is, the leaden matter, which is to be rejected as useless. The powder of the calamine will settle at the bottom of the vessel, where, after pouring off the water, it may be found, and used as above directed.

In this operation the charcoal-dust serves to prevent both the copper and the zinc from being calcined: and for this reason, when you work on a great quantity of materials at once, it is not necessary to use so much charcoal dust, in proportion, as when you work but on a small quantity; because, the greater the mass of metal, the less easily it will calcine,

Though the copper melts in this operation, yet it is far from being necessary to apply such a strong fire as copper usually requires to melt it: for the accession of the zinc, on this occasion, communicates to it a great degree of fusibility. The increase of its weight is also owing to the quantity of zinc combined with it. Copper acquires still another advantage by its association with this semi-metal for it remains longer in the fire without calcining.

Brass well prepared ought to be malleable when cold. But in whatever manner it be made, and whatever proportion of zinc there be in it, it is constantly found quite unmalleable when red-hot.

Brass melted in a crucible, with a fierce heat takes fire almost like zinc, and from its surface many white flowers ascend, dancing about in flakes like the flowers of zinc. They are indeed the flowers of zinc, and the flame of brass urged by a strong fire is no other than the flame of the zinc that is united with the copper, and at that time burns. If brass be thus kept long in fusion it will lose almost all the zinc it contains. It will also lose much of its weight and its colour will be nearly that of copper. It is therefore necessary, towards performing

performing this operation aright, to seize the moment when the copper is sufficiently impregnated with zinc, when it hath acquired the most weight and the finest colour, with the least detriment to its ductility, that is possible, and that instant to put out the fire; because, if the copper be left longer in fusion, it will only lose the zinc already united with it. Skill acquired by much practice, and an acquaintance with the particular calamine employed, are necessary to guide the artist surely through this operation; for there are very considerable differences between the fundry ores of zinc. Some of them contain lead, as was said above, and in others there is iron. When these heterogeneous metals come to be mixed with the copper, they do indeed augment its weight, but they render it at the same time pale, and make it very harsh. Some calamines require to be roasted before they can be used for this purpose, and in the torrefaction emit vapours of a volatile alkali, succeeded by vapours of a sulphureous spirit: others exhale no vapours while roasting, and may be employed without any antecedent preparation. These different qualities must evidently produce great differences in the operation.

Brass may also be made, as Prince's metal and other imitations of gold are actually made, by using zinc in substance, instead of the ores that contain it. But these compositions have not, when cold, the ductility of brass prepared with *lapis calaminaris*, because zinc is seldom pure, or free from a mixture of lead. Perhaps also the different manner in which the zinc unites with the copper may contribute to this variation.

To obviate this inconvenience, the zinc must be refined from all alloy of lead. The property of being indissoluble by sulphur, which this semi-metal possesses, points out a very practicable method of doing it. The zinc must be melted in a crucible and stirred briskly with a strong iron wire, while

tallow and mineral sulphur are alternately projected upon it ; but so that the quantity of sulphur may greatly exceed that of the tallow. If the sulphur do not burn entirely away, but form a kind of scoria on the surface of the zinc, it is a sign that your semi-metal contains lead. In this case you must continue throwing in more sulphur, and keep stirring the zinc incessantly, till you perceive that the sulphur ceases to unite any more with a metallic substance, but burns freely on the surface of the zinc. The semi-metal is then refined ; because the sulphur, which cannot dissolve it, unites very readily with the lead, or other metallic substance, contained in it.

If zinc thus refined be mixed with pure copper in the proportion of a fourth or a third part, and the mixture be kept in fusion and constantly stirring for some time, the brass produced will be as ductile when cold, as that made by cementation with the *lapis calaminaris*.

With regard to prince's metal, and other imitations of gold, they are made either with copper or brass re-combined with more zinc. As it is necessary, for giving them a fine gold colour, to mix with them other proportions of zinc than that required to make brass only, they are generally much less ductile. In 1725, M. Geoffroy gave a memoir on this subject, in which he examined the effects of incorporating both copper and brass with zinc from a small to a very large quantity.

P R O C E S S IV.

Zinc dissolved in the Mineral Acids.

WEaken concentrated oil of vitriol by mixing with it an equal quantity of water. Into a matress put the zinc you intend to dissolve, first broken

broken to small pieces. Pour on it six times its weight of the vitriolic acid, lowered as above directed, and set the matrafs in a sand-bath gently heated. The zinc will dissolve entirely, without any sediment. The neutral metallic salt resulting from this dissolution shoots into crystals, which go by the name of *white vitriol*, or *vitriol of zinc*.

OBSERVATIONS.

Though zinc be soluble in all the acids, and when combined with those acids exhibits some uncommon phenomena, yet M. Hellot is the first that ever gave a particular account of what happens in those dissolutions: so that all we have to say on this head is extracted from that gentleman's memoirs. If a solution of zinc in the vitriolic acid, prepared according to the directions in the process, be distilled from a retort placed in a sand-bath with a graduated heat, almost half the liquor presently comes over in pure phlegm. A small quantity of a sulphureous acid spirit rises next. A greater force of fire is now requisite: the retort must therefore be removed into a reverberatory, and the distillation continued with a naked fire. On the first impression of this heat an odour of liver of sulphur discovers itself, which becomes sharp and suffocating towards the end of the distillation. In two hours time white vapours begin to appear, as in the rectification of common oil of vitriol. If the receiver be then shifted, you will obtain an oil of vitriol, in quantity about the eighteenth part of the whole used in the distillation, which, though sulphureous, is yet so concentrated, that, if a few drops thereof be poured into a weak oil of vitriol, they fall to the bottom with as much noise as if they were so many bits of red-hot iron, and heat this oil of vitriol as much as common oil of vitriol heats water.

At the bottom of the retort there remains a dry, white,

white, crystalline, saline mass, exceeding, in weight the zinc that was dissolved, about a twelfth part of the whole weight of the liquor. The increase of its weight is owing to a portion of the vitriolic acid that remains concentrated in the zinc, and could not be expelled by the fire. This portion of acid adheres to it most tenaciously: for, though M. Hellot kept the retort containing it during two whole hours in so violent a fire that the vessel began to melt, the smallest vapour did not rise from it.

This saline *caput mortuum* is in the form of needles, much like the sedative salt. It is caustic grows considerably hot when water is poured on it and gives in the air, but slowly. Spirit of wine digested with this salt for eight or ten days, acquires the same smell as that which is mixed with concentrated oil of vitriol in preparing æther.

Zinc is dissolved by the nitrous and marine acids much in the same manner as by the vitriolic; except that the marine acid does not touch a black spongy, rarefied matter, which it separates from the zinc. M. Hellot found upon trial that this matter is not mercury, and that it cannot be reduced to a metallic substance.

This ingenious chymist distilled likewise solutions of zinc in the nitrous and marine acids. There came over at first, as there did from the solution made by the vitriolic acid, an aqueous, and then an acidulated liquor. At last, by exciting the fire with great violence, towards the end of the distillation, he obtained a small quantity of the acid that hath been employed in the dissolution: but the small portion of acid thus obtained was exceedingly strong; and the quantity of the nitrous much more considerable than that of the marine acid.

A solution of zinc in the marine acid, being distilled to dryness, yields a sublimate on applying violent heat to it.

All the acids dissolve with ease, not only zinc, but its flowers also; and that nearly in the same quantity, and with almost all the same phenomena. Mr. Hellot, observing that the residues of most of the solutions of zinc have a great resemblance with its flowers, is of opinion that this semi-metal may be reduced, by the means of solvents, to the same state into which it is brought by the fire when sublimed in flowers.



C H A P. IV.

Of ARSENIC.

P R O C E S S I.

To extract Arsenic from its Matrices. Zafre or Smalt.

POWDER some cobalt, white pyrites, or other arsenical matters. Put this powder into a retort with a short wide neck, leaving a full third thereof empty. Set your retort in a reverberating furnace; lute on a receiver; heat your vessel by degrees, and increase the fire till you see a powder sublime into the neck of the retort. Keep up the fire in this degree as long as the sublimation continues: when this begins to slacken, raise your fire, and make it as strong as the vessels will bear. When nothing more ascends, let it go out. On unluting the vessels, you will find in the receiver a little arsenic in the form of a fine light *farina*. The neck of the retort will be full of white flowers, not quite so fine, some of which will appear like little crystals, and if a good deal of arsenic be sublimed, a ponderous matter, like a white, semi-transparent glass

glass, will be found adhering to that part of the neck of the retort which is next its body.

OBSERVATIONS.

Arsenic is a metallic substance still more volatile than zinc; so that it cannot be separated from the matters with which it is mixed otherwise than by sublimation. It is proper, however, to take notice that it is not naturally in a metallic form, and that, properly speaking, the whole sublimate obtained from cabalt, as above directed, is nothing but a metallic calx, that cannot be brought to the form and gloss of a metal, till it be worked up with fatty matters, as we shall shew in its place.

This calx is of a very singular nature, and differs from every other metallic calx, in that this is volatile, and all the rest extremely fixed; even those procured from the semi metals: for the flowers of zinc, which are justly considered as a calcined zinc, tho' obtained by a sort of sublimation, are not for all that of a volatile nature, but rather exceedingly fixed; seeing they are capable of sustaining the most violent fire, and melt instead of subliming. Arsenic, on the contrary, is not only extracted from its ore by sublimation, but when once sublimed continues to be volatile, and flies off in vapours as soon as it is exposed even to a moderate degree of heat.

This metallic matter, before it is combined with the phlogiston, is called *white arsenic*, or plain *arsenic*: it acquires the title of *regulus of arsenic* when it is united with the phlogiston, and glitters like a metal.

Though arsenic be volatile, yet it requires a pretty strong fire to separate it from the minerals containing it, especially in close vessels; because it adheres very close to earthy and vitrifiable matters. This adhesion is so firm, that, when thus combined,

it.

it is capable of bearing a melting heat, and vitrifies with metallic calxes, and other fusible matters. On this account it is impossible to extract from cobalt, or other arsenical matters, all the arsenic they contain by working them only in close vessels. If such matters are to be freed from all their arsenic, you must, after you have extracted all they will yield by distillation, put them into a crucible, and set it uncovered in the midst of a strong fire. Many arsenical vapours will still rise; and care must be taken to stir the contents of the crucible frequently with an iron rod, to facilitate the discharge of the remaining arsenic.

It often happens that the arsenic, obtained from minerals by sublimation, is not very white, but of a lighter or darker grey colour. This is owing to some particles of inflammable matter, from which arsenical minerals are seldom quite free. A very small quantity of phlogiston is sufficient to deprive much arsenic of its whiteness, and to give it a grey colour. But when fouled in this manner, it may easily be brought to its due degree of whiteness: it need only be sublimed once more, after mixing it with some substance on which it doth not act; sea-salt, for instance. If the matters from which arsenic is extracted contain sulphur also, as some pyrites do, the arsenic sublimes with much less heat, than when it is united with earthy matters only; because it combines with the sulphur, wherewith it hath a great affinity, and the sulphur serves to separate the arsenic, by this interposition, from the earth. In consequence hereof, sulphur may be employed to extract arsenic, out of the earths in which it is fixed. In this case, the sulphur changes the colour of the arsenic, which it makes of a lighter or deeper yellow, or even red, in proportion to the quantity there is of it, and to the degree of fire that hath acted on both together.

The consistence of arsenic is different, according to

to the degree of heat applied in subliming it. If the arsenical vapour meet with a cold place, it gathers there in the form of a powder, as the flowers of sulphur do : this is the case with that which falls into the receiver in distilling it. But, if it be stopped in a hot place, and cannot escape from that heat it condenses into a heavy, compact, semi-transparent body, having undergone the first degree of fusion.

Yet it cannot be perfectly melted, so as to flow like other fused matters : not that it is refractory ; for, on the contrary, the degree of heat in which it begins to melt is very moderate, and it is in its own nature very fit to promote the fusion of refractory matters : but the reason is this ; it is necessarily converted into vapours by the degree of heat necessary to fuse it, and these vapours burst the vessels, if they find no vent.

Arsenic made yellow by a mixture of sulphur, which is also called *orpiment*, is reducible to the form of a solid sublimate with more ease ; because it is alloyed with a twentieth, or perhaps a tenth part, of its weight of sulphur, which renders it more fusible.

Red arsenic, which contains still more sulphur, melts also more easily. It then becomes of a transparent red, like a ruby : and hence, when it is in this form, it is called *ruby of arsenic*.

When a combination of sulphur and arsenic is wanted, it is better to mingle and distill together such minerals as contain sulphur and arsenic, the white and the yellow pyrites, for instance, than to mingle pure arsenic with pure sulphur : for the great volatility of these two substances is a hindrance to their uniting ; whereas, when combined with other matters, they are capable of sustaining a much greater degree of heat, which favours and promotes their union.

Those who work by the great do not extract arsenic out of cobalt by distillation : they throw the ore

ore mixed promiscuously with wood and charcoal into a great furnace, from whence a flue carries the vapours into a long winding passage, across which beams of wood are fixed at proper distances from each other. The arsenical vapours being conducted into this passage, adhere both to the sides thereof and to the joists that lye across it. The fuliginous parts of the combustible matters being lighter ascend higher, and go out through a chimney at the farther end of this passage.

The arsenic sublimed by this method is not white, but of a grey colour; owing to the inflammable matter of the wood and charcoal, with which the ore is torrefied.

When all the arsenic the cobalt will yield is thus separated, the earthy fixed matter left behind is mixed with divers fusible matters and vitrified, and produces a glass of a beautiful blue colour. It is called *smalt*. This glass is to be prepared in the following manner.

Take four parts of fine fusible sand, an equal quantity of any fixed alkali perfectly depurated, and one part of cobalt from which the arsenic hath been sublimed by torrefaction. Pulverize these different substances very finely, and mix them thoroughly together; put the mixture into a good crucible, cover it, and set it into a melting furnace. Make a strong fire, and keep it up constantly in the same degree for some hours. Then dip an iron wire into the crucible; to the end of which a glassy matter will stick, in the form of threads, if the fusion and vitrification be perfect. In this case take the crucible out of the fire; cool it by throwing water on it, and then break it. You will find in it a glass, which will be of an exceeding deep blue, and almost black, if the operation hath succeeded. This glass, when reduced to a fine powder, acquires a much brighter and more lively blue colour.

If

If you find after the operation that the glass hath too little colour, the fusion must be repeated a second time, with twice or thrice the quantity of cobalt. If, on the contrary, the glass be too dark, less cobalt must be used.

Instead of the mixture here prescribed you may employ a ready made glass, providing it be white and fusible. But as glass is always hard to melt, and as the mixing cobalt with it renders it still more refractory, therefore though an alkaline salt be one of the ingredients in its composition, it is proper to promote the fusion, by mixing therewith calcined wine-lees, in the quantity of one third part of the weight of the cobalt.

In order to make the assay of a particular cobalt, with a view to know what quantity of blue glass it will yield, it is not necessary to perform the operation in the manner here set down; a great deal of time and trouble may be saved by melting one part of cobalt with two or three parts of borax. This salt is very fusible, and turns, when melted, into a substance which, for a time, possesses all the properties of glass. In this trial the glass of borax will be nearly of the same colour as the true glass, or smalt, made with the same cobalt.

The ores of bismuth, as well as cobalt, yield a matter that colours glass blue; nay, the smalt made with those ores is more beautiful than that procured from the ore of pure arsenic. Some cobalts yield both arsenic and bismuth. When such cobalts are used it is common to find at the bottom of the crucible a little button of metallic matter, which is called *regulus of cobalt*. This regulus is a sort of bismuth, generally adulterated with a mixture of ferruginous and arsenical parts.

The heaviest and most fixed flowers of arsenic, procured from cobalt, have likewise the property of giving a blue colour to glass. But this colour is faint: it is owing to a portion of the colouring

matter

matter carried up along with the arsenic. These flowers may be made an ingredient in the composition of blue glass, not only because of the colouring principle they contain, but also because they greatly promote fusion; arsenic being one of the most efficacious fluxes known.

In short all those blue glasses, or smalts, contain a certain quantity of arsenic; for a portion of this semi metal always remains united with the fixed matter of the cobalt, though roasted for a long time, and in a very hot fire. The portion of arsenic that is thus fixed vitrifies with the colouring matter, and enters into the composition of the smalt.

The blue glass made with the fixed part of cobalt hath several names, according to the condition in which it is. When it hath undergone the first imperfect degree of fusion only it is called *Zaffre*. It takes the name of *Smalt* when perfectly vitrified: and this again being pulverized is called *powder blue*; or, if finely levigated, *blue enamel*; because it is used in enamelling, as well as in painting earthen ware and porcelain.

P R O C E S S II.

To separate Arsenic from Sulphur.

POWDER the yellow or red arsenic which you intend to separate from its sulphur. Moisten this powder with a fixed alkali resolved into a liquor. Dry the mixture gently; put it into a very tall glass cucurbit, and fit on a blind-head. Set this cucurbit in a sand bath; warm the vessels gently, and increase the fire by degrees, till you perceive that no more arsenic sublimes. The arsenic, which before was yellow or red, rises into the head partly in white flowers; and partly in a

compact, white, semi-transparent matter, which looks as if it were vitrified. The sulphur combined with the fixed alkali remains at the bottom of the cucurbit.

OBSERVATIONS.

A fixed alkali hath more affinity than any metallic substance with sulphur: so that it is not surprising sulphur should be separated from arsenic by its interposition. Yet there is an inconvenience attends the use of it: for it hath a great affinity with the arsenic also, and so always retains some part thereof, which continues fixed with it. For this reason care should be taken not to mix, with sulphurated arsenic, a greater quantity of alkali than is necessary to absorb the sulphur it contains. Nothing however, but experience and repeated trials can teach us the exact quantity of alkali that ought to be employed; because the quantity of sulphur that may be contained in yellow or red arsenic is indefinite.

The vessel ought to be tall, that the upper part of the head, where the arsenical particles condense, may be the less exposed to heat. Towards the end of the operation the fire must be strongly excited, so as to make the sand red-hot; because the last portion of arsenic that rise are strongly retained by the fixed alkali.

Arsenic that is grey or blackish may be depurated and whitened by the same means; because a fixed alkali absorbs the phlogiston likewise with great avidity. Mercury, as well as a fixed alkali, is an excellent additament for separating arsenic from sulphur. If you will use it for that purpose, reduce the sulphurated arsenic to a very fine powder, by rubbing it a long time in a glass mortar; when it is well pulverized, let a few drops of mercury fall upon it, by squeezing it through chamoy, and
continue

continue the trituration. The yellow or red colour of the arsenic will insensibly change, and gradually grow darker as the mercury incorporates with it. When the mercury is perfectly killed, add a little more of it than you did the first time, and in the same manner: continue to triturate till it disappear; and thus go on adding more and more till the mercury you add remain quick, and you can kill no more of it. Neither the red nor the yellow colour will then appear in the mixture: which will be grey, if it contain but a little sulphur, and black, if a great deal.

Put this mixture into a very tall glass cucurbit; fit on a blind head; set it in a sand-bath, and bury it in the sand as far as the contained mixture reaches. Heat the vessels, and, during the whole operation, keep up a degree of fire a little weaker than that required for subliming cinabar. White arsenical flowers will adhere to the upper part of the head, amongst which will be some beautiful crystals of arsenic; and underneath them you will find some cinabar sublimed, but not entirely free from arsenic. If you desire to have your cinabar and your arsenic purer, and more unmixed with each other, separate the upper sublimate, which is arsenical, from the lower, which consists chiefly of cinabar. Powder each of them coarsely, and sublime them separately each in a different cucurbit.

On this occasion the mercury separates the sulphur from the arsenic, because it hath a greater affinity than arsenic with that mineral. It is not the only metallic substance of this character: for, as hath been shewn, there are several others that have a greater affinity than mercury with sulphur, being able to decompose cinabar by their interposition. Yet those metallic substances must not be substituted for mercury in the present operation: because there is none of them but hath at the same time a

very great affinity with arsenic, or even as strong an one as they have with sulphur; whereas mercury will by no means unite with arsenic.

This method of separating arsenic from sulphur hath two advantages over that in which a fixed alkali is the medium. The first is, that by this means all the arsenic contained in the mixture is extracted out of it; and the second, that, as mercury doth not absorb arsenic, we are not put to the trouble of groping out, as it were by trials the quantity necessary to be added; and that, though more be added than is necessary to absorb all the sulphur, is will be of no prejudice to the operation. But then it is attended with the inconvenience of being much more tedious and more laborious than the other. For, in the first place, it requires previously a very tiresome trituration, in order to procure an union between the sulphur and the mercury, and so to form an æthiops; without which the mercury and the sulphurated arsenic will sublime separately, so that no decomposition will be effected. Secondly, though the mercury be sufficiently united with sulphur of the arsenic by the long trituration that precedes the sublimation, this doth not prevent, as we took notice above the sublimed arsenic and cinabar from being in some measure blended together; so that each requires a second separate sublimation to render it very pure.

These inconveniences cause a fixed alkali to be used preferably to mercury; the loss of a small quantity of the arsenic, which remains united with the alkali, being little regarded; as that metallic substance is neither scarce nor precious.

When arsenic is united with a great quantity of sulphur, it may be freed from a part thereof without the intervention of any third body: it is sufficient for the purpose to sublime it with a very gentle fire, encreased by insensible degrees. The most sulphureous

fulphureous part ascends first; what rises afterwards is more arsenical and less sulphureous; and the last flowers of all are pure arsenic, or at least nearly so.

PROCESS III.

To give Arsenic the Metalline Form. Regulus of Arsenic.

TAKE two parts of white arsenic in fine powder, one part of the black flux, half a part of borax, and as much clean iron filings. Rub the whole together, in order to mix them thoroughly. Put this mixture into a good crucible, and over it put sea-salt three fingers thick. Cover the crucible; set it in a melting furnace, and begin with a gentle fire to heat the crucible equally.

When arsenical vapours begin to ascend from the crucible, raise the fire immediately so as to melt the mixture. Examine whether or no the matter be thoroughly melted, by introducing an iron wire into the crucible; and if the fusion be perfect take the crucible out of the furnace. Let it cool; break it; and you will find in it a regulus of a white and livid metallic colour, very brittle, scarcely hard, but rather friable.

OBSERVATIONS.

White arsenic is, as hath been said, a metalline calx; and consequently wants no more, in order to its acquiring the metalline properties, than to be combined with the phlogiston: this is effected by the operation before us.

The iron added doth not serve here, as in making the regulus of antimony, to precipitate the regulus of arsenic, by separating it from some other substance

substance with which it was united ; on this occasion it does nothing but join the regulus of arsenic, to which it gives solidity and consistence. This is the only reason of it being made an ingredient in the mixture ; as the regulus of arsenic, without it would have such a tender consistence, that it could scarce be handled without falling asunder into little bits. The iron procures a further advantage in this process ; which is, that it prevents a great quantity of arsenic from being lost in vapours : for the arsenic, with which it combines, is restrained, and, in some measure, fixed by it.

Copper may be substituted for iron, and procures the same advantages.

It is very necessary to remove the crucible from the fire as soon as the matter is melted, and indeed to cool it as expeditiously as possible, to prevent the arsenic from flying off in vapours : for, when once the regulus is formed, the proportion of arsenic, with respect to that of the metal mixed with it, is continually lessening while it stays in the fire ; so that, after some time, there will be left in the crucible, not a regulus of arsenic, but only iron or copper, alloyed with a little arsenic. On this occasion the copper turns white, and assumes the colour of silver ; but it soon tarnishes in the air.

It is easy to perceive, by what hath been said, that the regulus of arsenic made according to this process is never pure, but contains always a considerable quantity of iron or copper, whatever precautions be used : but it is difficult to avoid this inconvenience, for the reasons above assigned ; and if we attempt to fuse arsenic alone, with reducing fluxes, the greatest part thereof is dissipated in vapours, long before the very flux begins to melt : and that part of it, which is found metallized, is not collected in one mass at the bottom of the crucible, as in other metallic reductions ; but in small particles, dispersed and mixed among the scorixæ.

There

There are nevertheless several expedients for obtaining a regulus of arsenic absolutely pure, and unalloyed with any metallic substance.

First : into a little low cucurbit, covered with a blind head, put regulus of arsenic made with iron or copper ; set this cucurbit in a sand-bath ; heat it till the sand begins to grow red ; and you will see part of the regulus sublime into the head, still retaining its metallic splendour. The portion of regulus thus sublimed is pure arsenic, or at least contains but a very small portion of the adventitious metal, which may have been carried up with it. What is left in the bottom of the cucurbit is the metal that was added, still containing a little arsenic, which continues obstinately fixed with it, and which the violence of fire is unable to force away from it in close vessels.

Secondly : mix your arsenic in equal parts with the black flux ; put the mixture into such a cucurbit as that last mentioned ; and apply to it the strongest degree of heat that can be procured by a sand-bath ; arsenical flowers, of a blackish grey colour, will first sublime into the head, and after them a regulus of arsenic of a white metalline colour, which is pretty glossy, but tarnishes very soon in the air. This regulus hath no solidity ; it is exceeding friable ; but it is pure.

Thirdly : I have also made a regulus of pure arsenic by another method, which produces a much greater quantity thereof, with a much smaller degree of heat. For this purpose I powder the arsenic, and mix it with any fat oil ; so that the mixture may be like a liquid paste : this paste I put into a little phial of thin glass, like one of those used by apothecaries ; I set this phial in a sand-bath, and gradually heat it, till the bottom of the pot containing the sand begin to be red. Part of the oil first rises out of the phial in vapours, which must be suffered to pass off. After this the upper part of the

the phial is gradually lined, on the inside, with a glittering metallic crust, which makes it look like a quick-silvered glass. This crust is the regulus of arsenic. When it begins to sublime, the mouth of the phial must be slightly stopped with a bit of paper, and the heat increased a little, till you see that nothing more rises.

If you break the bottle after the operation, you will find its upper part crusted over with a coat of regulus, thicker or thinner in proportion to the quantity of arsenic employed. The regulus is in a mass, of a beautiful brilliant colour, which to me seems to stand the air better than that of any regulus made by other methods; probably because of the great quantity of fat matter with which it is united, and by which it is defended.

This regulus of arsenic is absolutely pure, and a much greater quantity thereof is obtained, by this method, than by treating it with the black flux; because the arsenic is much sooner and more easily combined with the inflammable matter: and hence it comes to pass that part of the arsenic doth not rise at first in grey flowers, as in operating with the black flux. Moreover, by our process, all the arsenic is sublimed in regulus: whereas, when the black flux is employed, a pretty considerable part of the arsenic unites with the alkaline part of the flux, and remains fixed therewith. In our operation there is nothing left at the bottom of the phial, except an oily, light, but very fixed coal.

Regulus of arsenic, in whatever manner made, may be easily reduced into white, crystalline arsenic, by the means of a fixed alkali, or of mercury, applied in the same manner as for separating arsenic from sulphur.

P R O C E S S IV.

To distill the Nitrous Acid by the interposition of Arsenic. Blue Aqua Fortis. A new Neutral Salt of Arsenic.

PUlverize finely any quantity you please of refined salt-petre. Mix it accurately with an equal weight of white crystalline arsenic, well pulverized, or else with very white and very fine flowers of arsenic. Put this mixture into a glass retort, leaving one half of it empty. Set your retort in a reverberating furnace; apply a receiver having a small hole drilled in it, and containing a little filtered rain-water; lute the receiver to the retort with stiff lute. Begin with putting two or three small live coals in the ash-hole of the furnace, and replace them with others when they are ready to go out. Go on thus warming your vessels by insensible degrees, and put no coals in the fire-place, till the retort begin to be very warm. You will soon see the receiver filled with vapours of a dark-red, inclining to a russet colour. With a bit of lute stop the little hole of the receiver. The vapours will be condensed in the water of this vessel, and give it a very fine blue colour, that will grow deeper and deeper as the distillation advances. If your salt-petre was not very dry, some drops of acid will also come over, and falling from the nose of the retort mix with the water in the receiver. Continue your distillation, increasing the fire little by little as it advances, but exceeding slowly, till you see that when the retort is red-hot nothing more comes off; and then let your vessels cool.

When the vessels are cold, unlute the receiver, and, as expeditiously as you can, pour the blue *aqua fortis* it contains in a crystal bottle; which you must

must seal hermetically, because this colour disappears in a short time when the liquor takes air. You will find in the retort a white saline mass moulded in its bottom, and some flowers of arsenic sublimed to its upper cavity, and into its neck.

Pulverize the saline mass, and dissolve it in warm water. Filter the solution, in order to separate some arsenical parts that will be left on the filter. Let the filtered liquor evaporate of itself in the open air; when it is sufficiently evaporated, crystals will shoot in it representing quadrangular prisms, terminated at each extremity by pyramids, that are also quadrangular. These crystals will be in confused heaps at the bottom of the vessel: over them will be other crystals in the form of needles; a saline vegetation creeping along the sides of the vessel; and the surface of the liquor will be obscured by a thin dusty pellicle.

OBSERVATIONS.

Arsenic, as we took notice in our elements of the Theory, besides the properties it hath in common with metallic substances, possesses others also in common with saline substances. One of the most remarkable among the latter is that of decomposing nitre; of expelling the acid of that salt from its alkaline basis, assuming its place, and forming with that alkali a neutral salt, which is very soluble in water, and shoots into regular crystals.

To enquire into what passes in the decomposition of nitre by arsenic, and into the new salt resulting from thence, was the design of the first memoir given in by me to the Academy of Sciences on this subject, and from that the present process is copied. Though the whole quantity of arsenic prescribed in the process doth not enter into the composition of the new neutral salt, seeing some of it sublimes in flowers, that quantity must not there-
fore

fore be thought too great; for we see, on the other hand, that part of the nitre, is not decomposed. The needle-like salt is no other than nitre that hath not suffered any decomposition, and actually deflagrates on live coals like common nitre.

The precaution of putting some water in the receiver is absolutely necessary, to condense the nitrous vapours that rise in the distillation: for they are so elastic, so volatile, so dephlegmated, that a very small part of them will otherwise be condensed into a liquor, while the rest will remain in the form of vapours, to which vent must be given through the small hole in the receiver, as without that they will burst the vessels with impetuosity: and consequently scarce any acid will be obtained; especially if the nitre employed be very dry, as it must be to be reducible into a fine powder.

The blue colour communicated by the nitrous acid to the water is very remarkable. The cause that produces this colour is not yet known.

Though the acid is, on this occasion, mortified by a great quantity of water, yet, when it rises out of the retort, it is so concentrated as to form, even with that water, if too much be not put in, a most active and even smoking *aqua fortis*.

It is necessary in this operation, and more so than in any other, to warm the vessels gradually, and to proceed exceeding slowly; otherwise the artist runs the risque of seeing his vessels burst to pieces with violence, and with great danger to his person: for arsenic acts on nitre with incredible vivacity; in so much that, if a mixture of nitre and arsenic be heated to a certain degree, the nitre is decomposed almost as rapidly, and with as great an explosion, as when it is made to fulminate with an inflammable matter. In short, the appearances are such, that one would be almost induced to think the nitre really takes fire on this occasion; though it be only decomposed just as it is by the vitriolic acid.

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The solution of the *caput mortuum* of this distillation contains, at the same time, several sorts of salts : to wit, 1. the neutral salt of arsenic, formed by the union of the arsenic with the basis of the nitre ; this shoots into the prismatic crystals above mentioned : 2. some nitre that hath not been decomposed ; this forms the needles and part of the vegetations ; 3. a small portion of arsenic, that is known to be soluble in water, this forms the thin dark pelicle that covers the surface of the liquor when it begins to evaporate.

For the properties of this new neutral salt of arsenic you may consult what we have said thereupon in our Elements of the Theory, and in the memoirs of the academy of sciences.

PROCESS V.

To alkalizate Nitre by Arsenic

MELT in a crucible the nitre you intend to alkalizate. When it is melted, and moderately red, project upon it two or three pinches of pulverised arsenic. A considerable effervescence and ebullition will immediately be produced in the crucible, attended with a noise like that which nitre makes, when it detonates with an inflammable matter. At the same time a thick smoke will rise which at first will smell like garlic, the odour peculiar to arsenic ; it will also smell afterwards like spirit of nitre. When the effervescence in the crucible is over, throw again upon the nitre as much pulverized arsenic as you did the first time ; and all the same phenomena will be repeated. Continue thus throwing in arsenic in small parcels, till it produce no more effervescence ; taking care to stir the matter at every projection with an iron wire the better to mix the whole together. Then increase your fire, and melt what remains. Keep it thus

in fusion for a quarter of an hour, and then take the crucible out of the fire. It will contain a nitre alkalized by arsenic.

OBSERVATIONS.

This operation, as well as the preceding one, is a decomposition of nitre by arsenic; yet the result is very different: for, instead of a salt capable of crystallizing, and discovering no tokens either of acid or alkali, we obtain, on this occasion, only a salt that runs into a liquor by the moisture of the air, doth not crystallize and hath all the properties of an alkali.

These differences arise only from the different manner in which the decomposition of the nitre, and the union of the arsenic with the basis of that salt, is brought about. When the nitrous acid is distilled by the interposition of arsenic, with a view to obtain the arsenical salt the operation must be performed in close vessels; no greater degree of heat must be applied to the mixture than is necessary for enabling the arsenic to act; and that heat must be administered very slowly and by insensible degrees. But, when the business is to alkalize nitre by the means of arsenic, the operation is performed in a crucible, in a naked fire, with a strong degree of heat, and that suddenly applied. The violence of the heat, the suddenness with which it is applied, the vivacity wherewith the arsenic unites with the basis of the nitre; and, still more than all these, the free access of the air, occasion the greatest part of the arsenic, which at first combines with the basis of the nitre, after having expelled its acid, to be presently carried off and dissipated in vapours; and consequently the basis of the nitre, not being sufficiently saturated, discovers its alkaline properties.

I say the concurrence of the air contributes, still

more than all the rest, to separate the arsenic from the alkaline basis of the nitre ; experience having taught me that the neutral salt of arsenic is not to be alkalized by the most violent force of heat, as long as it continues in close vessels, and the external air hath no communication with it ; but that some of the arsenic contained in that salt is dissipated, by exposing it to a strong heat in open vessels.

The tumult and effervescence that arise, when arsenic is projected on nitre fused in a crucible, are so considerable, and so nearly resemble the detonation of nitre with an inflammable matter, that we should be tempted to think, if we trusted appearances only, that arsenic furnishes a combustible matter, and that the alkalization of the nitre is effected, on this occasion, in the same manner as when it is fixed by charcoal : but, by examining attentively what passes, we easily discover that there is no inflammation at all, and that the nitre is alkalized in the manner and by the means above pointed out

The first vapours that rise, when arsenic is projected on nitre, are purely arsenical ; and, if any cold body be put in their way, they adhere to it in the form of flowers. These vapours are actual particles of arsenic, carried up by the heat before they could come to act on the nitre ; but they are soon after mixed with nitrous vapours, consisting of the acid of the nitre, which the arsenic expels from its basis as fast as it comes to act on that salt.

The nearer you come to the end of the operation, the more does the matter in the crucible lose of it's fluidity, though an equal fire be constantly kept up in the furnace. At last it becomes quite like a paste, and the fire must be made much stronger to put it again in fusion. The reason of this is, that nitre when alkalized is much less fusible than

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when it is not so. The case is the same when this salt is alkalized by deflagration.

Though the nitre, when alkalized, makes no more effervescence with arsenic, and though, when kept in fusion, it emits no more arsenical vapours, it doth not thence follow that it is a pure alkali, and that it contains no arsenic: it still contains a large quantity thereof, but so strongly united that the force of fire is not able to separate them; which hath led some authors to give this salt the title of *fixed arsenic*.

The existence of arsenic in this same compound is easily discovered, by fusing it with a metallic substance, on which it produces the same effects as arsenic.

With solutions of metals in the acids, it also presents almost the same phenomena as the neutral salt of arsenic. Particularly it precipitates silver dissolved by the nitrous acid in a red powder, as that salt does; and the differences observed between the precipitations made by our new neutral salt of arsenic, and those made by nitre alkalized with arsenic, can be attributed only to the alkaline quality of the latter. See the Memoirs of the Academy for 1746.



P A R T II.

OF VEGETABLES.



SECTION I.

Operations on unfermented Vegetables.



CHAP. I.

OF THE SUBSTANCES OBTAINED FROM VEGETABLES BY EXPRESSION ONLY.

PROCESS I.

To express and depurate the juice of a Plant, containing its Essential Salt. The Crystallization of that Salt,

BEfore sun-rise, gather a good quantity of the plant from which you design to express the juice, in order to obtain its salt. Wash it well in running water, to clear it of earth, insects, and other adventitious matters. Bruise it in a marble mortar; put it into a bag of new, strong, thick linen cloth; tye the bag tight, and commit it to a press. By pressing it strongly you will squeeze out a great quantity of green, thick juice, which will have the same taste as the plant. Dilute this juice with six times as much pure rain-water, and filter

it repeatedly through a woollen bag, till it pass clear and limpid. Evaporate the filtered juice with a gentle heat, till it be almost as thick as before it was mixed with water. Put this inspissated juice into a jar, or other vessel of earth or glass; on its surface pour olive oil to the depth of a line, and set it in a cellar. Seven or eight months after this, pour off gently the liquor contained in the vessel, the inside of which you will find covered with a crystallized salt. Separate the crystals gently; wash them quickly with a little fair cold water, and dry them: this is the essential salt of the plant.

OBSERVATIONS.

Every plant is not equally disposed to yield its essential salt, by the method here proposed. Succulent vegetables only, whose juices are aqueous and not too viscous, are fit for this purpose. Such for example as sorrel, brook-lime, succory, fumitory-water-creffes, plantain, &c.. An essential salt cannot be procured from those that yield thick, viscid, mucilaginous juices, such as the seeds of fleawort; unless their juices be previously attenuated by fermentation, and that viscosity destroyed which obstructs the crystallization of this salt.

Nor can the essential salt be obtained in any quantity from vegetable matters abounding in oil. Most kernels and seeds are of this sort: they all contain a great quantity of fat oil, which so entangles and clogs this salt, that the particles thereof cannot shoot away from the tenacious juices into crystals.

The same is to be said of dry aromatic plants; because they contain much essential oil, or resinous matters that produce the same effect. It is true the essential salt itself contains a certain portion of oil; for it is no other than the acid of the plant incorporated and crystallized with part of its oil and

of its earth ; but then the oil must not be in too great a quantity ; because it sheaths the acid, renders it clammy, as it were, and hinders it from extricating itself, so as to be able to exert its qualities and appear in the form of salt.

The plants, from which you intend to extract this salt, should be gathered in the morning before sun-rise ; because they are then most succulent, not being yet dried up or withered by the heat of the sun.

The juice of plants obtained by expression is very thick ; because it contains many particles of the bruised plant, that are unavoidably squeezed out along with it. In order to clear it of these superfluous parts, it is proper to filter it ; but as that would be difficult, on account of the thickness of the juice, it must be thinned, by diluting it with a quantity of water, sufficient to give it the requisite degree of fluidity.

Instead of thus diluting the expressed juice, the plant may be ground with water, before it is put into the press : it will by this means furnish a more fluid juice, that will easily pass through the filter. This method may be employed with success on dry plants, or such as are not very succulent. For this operation rain-water is to be preferred to any other ; because it is the purest : for all waters that have run some time through the earth, or on its surface, are to be suspected of containing some saline or selenitic matter, which would mix with and deprave the essential salt.

The juice of the plant, when diluted with the quantity of water sufficient to facilitate its filtration, is too aqueous to let the salt it contains unite into crystals : it must therefore be evaporated, till it hath recovered a somewhat thicker consistence. The heat applied for that purpose must be gentle ; lest the acid and oily parts, that are to form the salt, be spoiled or dissipated, as they are not very fixed.

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In summer, the heat of the sun is sufficient to effect this evaporation: but if you make use of this method, the juice to be evaporated must be put into several broad flat pans; that, a larger surface being exposed to the action of the air and sun, the evaporation may be the sooner completed: for if the juice should continue too long in the degree of heat requisite for its evaporation, it might begin to ferment: which would be very detrimental.

The oil poured on the liquor prevents its fermenting, putrefying, or growing mouldy, during the long space of time required for the crystallization of the essential salt.

These salts are excellent medicines, being endued with the same virtues as the plants from which they were obtained.

They cannot be procured from plants by distillation, though they consist in a great measure of volatile principles: nor are they obtainable by any other process that requires much heat; because they are easily decomposed, and the fire changes their natures entirely. The oily acids extracted from plants by distillation do not crystallize, and always have an empyreumatic acrimony, that makes them very different from the essential salts, which are very mild and saponaceous.

P R O C E S S II.

To draw the Oils out of Kernels, Seeds, and Fruits, by Expression.

POUND in a marble mortar, or grind in a mill, the kernels, seeds, or fruits, out of which you intend to express the oil. If your matters be meagre, and grind to meal, suspend that meal in the steam of boiling water, in order to moisten it a little, and then dry it.

Tye

Tye up your matter thus prepared in a new, strong, thick, canvass bag, and put it into a press, between two iron plates previously heated in boiling water: squeeze it strongly, and you will see the oil run in streams into the receiving vessel.

OBSERVATIONS.

The fat oil of plants is particularly found in kernels, seeds, and some fruits; some kernels contain such a vast quantity thereof, that, on being, very slightly bruised in a mortar, they discharge it in great abundance. Sweet and bitter almonds, walnuts, and lint-feed, are all of this kind; and require no other management, but to be pounded and pressed, to make them yield a great deal of oil. But there are others more meagre, that being ground produce an almost dry flower. In order to facilitate the expression of the oil out of such, they must be exposed, when ground, to the steam of boiling water. For this purpose, the meal may be put into a fine sieve, and that suspended over a pan half-full of water kept boiling on the fire. The ascending vapours will moisten the flower, render it more unctuous, and facilitate the expression of the oil.

It is proper to dry it a little before it be put into the press; that it may yield as little water as possible along with the oil. Nevertheless, so much water happens now and then to be left in it, that some is expressed together with the oil: but as oil and water do not incorporate, they are easily separated after the operation is finished.

The extraction of the oil is also greatly facilitated by heating the plates, between which the oleaginous matters are squeezed: but they must not be made too hot, if you mean to have a very mild oil, designed either for aliment or for medicine; such as the oil of olives, and that of sweet almonds.

For

For this reason the plates must be warmed in boiling water only : if you heat them to a greater degree, you run the risque of giving an acrimony to the oils you express. But, when these oils are intended for other uses, the plates may be made hotter, because their heat increases the yield of oil.

It is remarkable that all the oils obtained by expression, with the precautions above recommended, are constantly very mild ; even though the matters from which they are extracted be in themselves very acrid. Mustard-seed, which is so acrid that it is even caustic, yields, by expression, an oil as mild as that of sweet almonds. But then the kernels, seeds, and fruits, from which the oils are extracted, must not be old ; because these oils, which are perfectly mild when fresh and new, become intolerably acrid when they grow old, and acquire this acrimony even in the fruit itself ; for it is observed that these fruits turn rancid as they grow old.

The fat oils obtained by expression are used in medicine, both internally and externally, as lenitives and emollients. Every body knows the great use of oil of sweet almonds, in inflammatory distempers of the breast and intestines. But it must be carefully noted, that these oils can produce no good effects, unless they be fresh expressed, and from fruits, kernels, or seeds that have not been long kept : for they not only lose their lenient virtue by growing old ; but they even acquire an opposite quality, and contract such a sharp acrimony, that far from procuring any salutary relief or mitigation to the inflamed parts, they are capable of irritating and inflaming the sound.

It is therefore of the last importance to administer them only when they are quite fresh : they ought never to be above two or three days old. Those that are old are generally more limpid and transparent

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parent than the fresh, which look a little more cloudy. The best way to distinguish them is to taste them, and to try whether or no they leave any sensation of rancidity on the palate and in the throat.

PROCESS III.

To draw the Essential Oils of certain Fruits by Expression.

TAKE the rind of a citron, lemon, orange, Bergamot-pear, or other fruit of that kind; cut it in slices, and, doubling the slices, squeeze them between your fingers, over against a polished glass set upright, with its lower end in a vessel of earth or porcelain. Every time you squeeze the peel in a new ply, there will squirt out of it several fine jets of liquor, which, meeting with the surface of the glass, will be condensed into drops, and trickle down in small streams into the recipient. This liquor is the essential oil of the fruit.

OBSERVATIONS.

No fruits but those of the kind above-mentioned will yield an essential oil by expression. The rind of the fruit is the reservoir of this oil: it is contained in little vesicles, which may be seen by the naked eye, spread all over the surface of the peel, and which, bursting when the peel is squeezed, discharge the oil in the form of very fine slender spouts. Every body knows that these little oily streams instantly take fire, when spirted through the flame of a candle: the oil, in this case is entirely consumed.

The essential oil, thus obtained by expression, hath a very sweet and most agreeable scent. It is in every respect the same as when it made a part of the

the fruit that yielded it ; seeing it hath not undergone the action of fire. Yet this method, however good it may be, can hardly be practised but in the countries where those fruits are in great plenty ; because we cannot by this means obtain any thing near the quantity of oil they contain.

This inconvenience may be remedied by rubbing the rind, which contains the essential oil, on the surface of a sugar-loaf. The inequalities of that surface produce the effects of a rasp, by tearing all the oily vesicles. The oil, which issues in abundance, is imbibed by the sugar and moistens it. When the sugar is sufficiently impregnated therewith, it may be scraped off with a knife, and put into a well-stopped bottle. The sugar does not alter the nature of the oil ; which may be kept in this manner for years, and used, though combined with the sugar, for almost all the same purposes as when in a fluid state ; that is, to aromatize the several matters with which you incline to mix it. We owe these observations to M. Geoffroy.

This experiment, in which the essential oil of a vegetable is obtained by expression alone, and without the aid of fire, proves that the oils of this kind exist naturally in vegetables ; and that the oils of the same kind obtained by distillation, as shall be shewn in its place, are not the product of the fire. Essential oils drawn by expression do not very sensibly differ from those procured by distillation.



C H A P. II.

OF THE SUBSTANCES OBTAINED FROM VEGETABLES BY TRITURATION.

P R O C E S S I.

To make the Extract of a Plant by Trituration.

BRUISE the vegetable substance of which you intend to make the extract ; or, if it be hard and dry, grind it to a powder : put the matter thus prepared, together with seven or eight times as much rain-water, into an earthen vessel ; and into this vessel fit a churning staff, so that it may be continually whirled round with a rotatory motion, by means of a cord, a wheel, and a winch. Ply this machine for ten or twelve hours ; and then filter the liquor through two linen cloths spread on a hair sieve. Let your filtered liquor stand quiet for twelve hours more : then pour it off by inclination from the sediment you will find at bottom ; and filter it a second time through a flannel bag.

Pour fresh water, but in a smaller quantity, on the mass left after trituration with the machine. Triturate it again for four or five hours. Treat the liquor of this second triture just as you did that of the first, and mix them both together. Distribute all the liquor you now have among a sufficient number of shallow earthen plates, and evaporate it by a gentle warmth, such as that of the sun, or of a vapour-bath, to the consistence of an extract, or even to dryness. as you think proper.

O B S E R.

OBSERVATIONS.

In trituration the water takes up, not only the salts of plants, but also a pretty considerable quantity of their oily and earthy parts, which those salts have rendered soluble therein, by communicating to them a sponaceous and mucilaginous quality. After trituration therefore nothing remains but the grossest particles of oil and earth. Hence it is evident that the water, in which plants have been triturated, contains nearly the same principles as the juices of those plants drawn by expression; and that it is also impregnated with their essential salts; so that, by evaporating it to a due consistence, we have a well made extract of the triturated plant.

The Count de la Garaye, who hath long cultivated, with great assiduity, those parts of Chymistry by which medicine may be improved, hath made a great number of experiments for obtaining from plants, by triture with water, the matters in which their virtues chiefly reside, and hath also published a work intituled Hydraulic Chymistry, in which he gives a particular account of all the processes for making such extracts of the chief mineral, vegetable, and animal substances, as are most frequently used in the practice of physick. His way of evaporating, by a gentle heat, the liquor containing the extract of a triturated substance is a very good one: for we know that heat, if but a very little too strong, is capable of changing the natures of compound bodies, by disuniting their principles, and exhaling some of them,

If all vegetable matters were fat and succulent, as most pot-herbs are, triture would not be necessary for the making an extract of them, even without the help of fire. We should have nothing to do, for that purpose, but to express their juices, as before, clarify them, and evaporate with a gentle

heat to the consistence of an extract. But many vegetable substances, such as woods, barks, roots, &c. are dry, hard, and compact. These matters will not give out their extract, without such an application of water as shall dissolve their saline, saponaceous, and mucilaginous parts. Now this must be effected either by triture, or by fire. Trituration has the advantage of procuring extracts, in which the principles are perfectly unaltered, and, retain the same proportions, with respect to each other, as in the plant: but then it is attended with the inconveniences of being very tedious, troublesome, and chargeable. When we come to deliver the methods of making extracts by decoction and by infusion, we shall see what are the advantages and disadvantages of preparing extracts by heat.

The matters, from which an extract is to be made by triture, must be previously bruised and reduced into small parts, in order to facilitate the action of water upon them. The several filtrations and decantations here directed are intended to separate the grosser parts of the plant, that were only suspended in the liquor, but not truly dissolved, by means of the agitation and motion: for this reason also, the longer the liquor is left to settle, the purer will the extract be.

Though the plant be triturated the first time with a great deal of water, and for a good while too, yet it is not by that means wholly exhausted: M. de la Garaye therefore directs the remainder to be triturated again with fresh water: but this second operation requires only half the water used in the former, and need be continued only half the time; the plant having been already opened by the former triture, and having fewer parts to give out. It is better to add fresh water, and triturate a second time, than to triturate but once, and for a greater length of time: for when the water is impregnated with the principles of the plant to a cer-

tain

tain degree, it is less capable of acting, and of dissolving more, than when it is pure.

As the water impregnated with the principles of the plant by triture must be almost wholly evaporated, in order to bring those principles nearer together, and that the whole may lie in the smallest compass possible; and moreover, as this evaporation must be effected by the gentlest heat, it is necessary to spread the liquor so, by distributing it among a great number of plates, that it shall be reduced in a manner entirely to surface. By this means the extract may be evaporated even to dryness; and this is M. de la Garaye's practice. As the extracts, thus evaporated to dryness, cannot be taken up otherwise than in little scales, the lower surfaces whereof, by adhering to the glazing of the plate, are smooth and shining, they in some measure resemble a crystallized salt; which led M. de la Garaye into an error, and induced him to give the title of essential salts to the extracts prepared in this manner. The essential salt is indeed contained in them: but still they are only extracts, as Mr Geoffroy hath shewn, in a memoir on this subject given in by him to the academy; since, besides the essential salt, they contain moreover, as was said before, a great deal of the oil and earth of the matters from which they were extracted. This, in the main, is no objection, but rather an advantage to them; considering that such saline extracts are, on that account, so much the more like the substances from which they were obtained; especially with regard to their medicinal properties.

PROCESS II.

To extract from Seeds and Kernels, by Trituration, the matter of Emulsions,

BLANCH the kernels of which you desire to make an emulsion; put them into a marble mortar: add a very light water; and pound them with a wooden pestle. Continue pounding and triturating till the matter become like a white paste. From time to time pour on it, by little and little, more fair water warmed, still continuing the trituration; by which means the paste will grow thinner. Go on thus till every particle of your kernels be crushed to pap. Then, add, still rubbing the mixture, enough of water to make the whole an actual fluid; and you will have a liquor of a dead white colour, resembling milk. Strain it through a clean linen cloth: it will leave on the filter some coarse parts, which must be returned to those left in the mortar. Again triturate and rub the remainder of the kernels, with the addition of water as before. This second liquor will not be so white nor so rich as the former: filter it in the same manner, and again grind with water the solid parts remaining. In this manner proceed, repeatedly rubbing and adding fresh water, till it appear no longer milky, but come off clear. The white milky waters thus obtained go by the name of an *Emulsion*.

OBSERVATIONS.

All the matters, from which a fat oil is obtainable by expression, produce emulsions when triturated with water.

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An emulsion consists chiefly of two substances. One of these is mucilaginous, and soluble in water. This substance by itself would not give a milky appearance to the emulsion, which, with it alone, would be limpid. The other is a fat oil, which of itself is not soluble in water; but being divided by the means of trituration into very small globules, it is dispersed through the whole liquor, and suspended therein by the aid of the mucilaginous part. It is this oily part that gives the emulsion its dead-white, milky colour; because it is not actually dissolved in the water, but only diffused through it.

If oil be mixed with water in a phial, and the mixture strongly shaken for some time, with a rapid and continued motion, the oil will be divided into a vast number of little globules, which intervening between the parts of the water will destroy its transparency, and give it a dead-white colour, like that of our emulsion. But, as the oil is not so minutely divided by this means, as by trituration the matters containing it; and again, there being no mucilage in this liquor, as there is in emulsions, the oil soon separates from the water when it is left at rest, re-unites into round globules, and these joining together rise to the surface of the liquor, which then recovers its transparency.

The case is not exactly the same with emulsions; but something like it happens to them also. If they be left to stand quiet in a long bottle, the liquor, which at first appeared homogeneous, separates into two manifestly different parts. The upper part retains its dead-white colour, but is thicker and more opaque; while the lower part becomes perfectly transparent. This is the beginning of an entire separation of the oily from the aqueous parts. The former, being the lighter, ascend and gain the upper part of the liquor; while the lower, being freed from that which obstructed its translucence, recovers its proper limpidity: but

the oily parts do not re-unite into masses large enough to form one homogeneous whole, with the appearance and limpidness of oil; their being minutely divided and entangled in the mucilage impeding their tendency.

Emulsions first begin to spoil, as they grow old, not by turning rancid and acrimonious like the fat oils drawn by expression, but by turning sour; which is owing to the great quantity of mucilage they contain. As there is a fat oil in their composition, they have the same virtues with that sort of oil; but they are moreover incrassating, cooling, and emollient; qualities which render them extremely useful in acute and inflammatory disorders. They grow sour in a very short time, especially in the heat of summer; nay, they sometimes do so in two hours: and therefore they ought to be prepared from time to time as they are to be used.

The matter that is left when all the substance of the emulsion is extracted, and from which the water comes off clear and limped, is scarce any thing but the earthy part of the seed or kernel that was triturated; which, however, still retains a portion of tenacious and gross oil, adhering to it so firmly as not to be separable by water.

The chyle and milk of animals resemble an emulsion in several respects, and particularly in their dead-white colour; which arises, in the same manner, from the very minute particles of oil contained in them, and distributed through an aqueous gelatinous fluid, but not dissolved therein. In general, whenever any oil of any kind happens to be lodged in this manner between the parts of an aqueous liquor, it always makes the whole of an opaque white: for oil will not mix with water, so as to produce a liquor that shall appear homogeneous and transparent, unless it be intimately dissolved in the water; which cannot be effected but by means of an union previously

previously contracted between it and some saline matter; as is the case of mucilages, certain saponaceous matters, and some other combinations of which we shall have occasion to treat in the sequel.

The methods we have hitherto proposed, for extracting from vegetable substances all that they will yield without the assistance of fire, are not capable of analyzing those substances accurately, as you may have observed; since by expression and trituration we obtain only the liquid parts, impregnated indeed with almost all the principles of plants, which however are still combined with each other, and barely separated from the grossest earthy and oily parts. We must therefore necessarily have recourse to a more effectual expedient for carrying our analysis further. This expedient consists in making them undergo the action of fire, successively graduated, from the gentlest to the most violent heat.

But, before we enter on this analysis of vegetables, it is proper to describe the different operations that may be performed on oils, the only pure principle we have been able to obtain without the help of fire. As we shall have occasion, when we come to treat of the analysis of plants by fire, to say a great deal more concerning essential oils, we reserve till then what relates to the operations that may be performed on them; and confine ourselves here to the operations on fat oils.



C H A P. III.

OF OPERATIONS ON FAT OILS.

P R O C E S S I.

To attenuate Fat Oils, and change their nature, by exposing them to the action of fire, and distilling them.

MIX thoroughly three or four pounds of any fat oil whatever, with twice its weight of lime flaked in the air. Put this mixture into a large earthen retort, leaving a third part of it empty. Set it in a reverberating furnace, and lute on a receiver. Heat the vessel with a very gentle fire. A little phlegm will rise first, and soon be followed by an oil that will fall in drops from the nose of the retort. Continue the distillation very slowly, till you perceive the oil that comes over begin to be not quite so fluid as before, but rather a little thicker.

Then unlute your receiver, and put another in its place. Continue the distillation, encreasing your fire by degrees. The oil that comes over will grow thicker and thicker, its fluidity will decrease, and it will acquire a dark brown colour, which at last will become blackish. The oil will then be very thick. Push the operation till nothing more will come off, though the retort be red-hot. During the whole time this distillation lasts, there rises a good deal of water, in company with the oil. Keep the second thick oil by itself.

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on, with an equal part of fresh lime flaked in the air. Put the mixture into an earthen or glass retort, of a size so proportioned to the quantity, that a third part thereof may remain empty. Distill as before. The same phenomena will appear: a clear oil will first come over, and be succeeded by one a little thicker. Then shift your receiver, and distill off all the rest of the oil with an increased fire. The first oil, obtained by this second distillation, will be clearer and thinner than that of the first distillation; and the second oil will not be so thick, nor of so deep a colour as before.

Distill over again, in the same manner, the thin oil of this second distillation, and go on thus repeatedly distilling, till the first clear oil come over with a degree of heat not exceeding that of boiling water. Then, instead of mixing your oil with lime, put it with some water into a glass retort, or into a body with its head fitted on, and distill it, keeping the water just in a simmer. Your oil will be more and more attenuated, and, after being thus distilled twice or thrice with water, will be so limpid, so thin, and so clear, that you will scarce be able to distinguish it from water itself.

OBSERVATIONS.

Fat oils, which are naturally mild, unctuous, inodorous, or have at most a scarce perceptible smell, resembling that of the fruit or kernel from which they were extracted, change their natures totally when exposed to the action of fire. If they be but heated so as to boil, they become acrid, lose much of their unctuousity, and acquire a very pungent odour. From several analogies, and by several experiments, recited in a memoir on oils which I read to the academy, I shewed that these alterations of fat oils are produced by the fire's extricating an acid in them, which before lay conceal-
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ed and inactive. What I advanced on this subject may be seen in the memoirs of the academy for 1745, and in my elements of the theory of chymistry. I shall take occasion to add something more, in my observations on the following process, by which these oils are combined with acids. In this place I shall only examine what passes in the repeated distillations they are here made to undergo.

Fat oils do not rise in distillation without a degree of heat greater than that of boiling water; and therefore they must be distilled in a sand bath, or with a naked fire. We prefer the latter method, for reasons elsewhere assigned, and chiefly because the operator is more master of his fire; it being absolutely necessary, in this operation, that he have it in his power to suppress it in an instant, when he finds it too strong: for, in such a case, it will impetuously raise the thin oil mixed with the thick; nay, the whole will be burnt, as it were, to a coal, if a degree of fire ever so little too strong be kept up but for a few moments. When this accident happens, it is always predicted by a great quantity of white vapours ascending with impetuosity out of the retort, and by drops of oil following each other very fast, that are scarce limpid at first, and soon become of a dark colour. All this may be prevented by distilling very slowly, and with great patience.

Fat oils may be distilled and attenuated without any additament: but then the operation, which is tedious and troublesome enough, even when lime is used, as appears from our description of the process, would be much more so if the oil were distilled alone, without the addition of any thing to divide it, spread it, and enlarge its surface.

Lime is one of the best additaments that can be employed on this occasion; not only because it procures the advantages just mentioned, but also

by reason that, being an absorbent of fat matters, it unites with the grosser parts of the oil, retains them, and so allows the thinnest and lightest parts to be readily separated from the rest. By this means it greatly expedites the operation; and, the more of it is added, with respect to the oil, the sooner is a considerable quantity of thin limpid oil obtained: and this is the reason of our directing a double quantity of lime to be mixed with the oil in the first distillation.

Lime slacked in the air is employed preferably to quick-lime; because it is naturally divided into a very fine powder, and capable of mixing perfectly with all sorts of matters.

The water that first appears in the distillation comes from the lime: it is part of the humidity which the lime had imbibed from the air. This water continues to rise with the oil during the whole distillation, according as the degree of heat is increased: and, if the distillation be finished by keeping the retort red-hot, for some time after all is come over, the lime in it will have a greyish cast, and, when water is poured on it, grow almost as hot as quick-lime.

If you resolve to carry on these distillations of a fat oil, till it become as light as an essential oil, it is necessary to begin with a pretty large quantity thereof, as three or four pounds: for the quantity of the oil is considerably lessened by every distillation; not only because the thickest and grossest part is separated from it every time; but also because a portion of the oil remains so strongly united with the lime, that the force of fire is not able to separate them. Moreover, there is reason to believe that some of it is decomposed every time it is distilled.

If oil be distilled by itself, the thickest and heaviest part remains charred, as it were, in the retort, the inside of which is lined with a crust of coal,

coal, that is to the last fixed : this therefore always occasions a diminution of the oil.

A fat oil must be distilled eight or nine times, even with lime, before it become as light as an essential oil, and capable of rising wholly with the heat of boiling water ; by that time therefore it must be considerably diminished ; and if, at least, the quantity prescribed be not taken at first, there will scarce remain a few ounces capable of being distilled with water.

The portion of thick heavy oil, obtained in the several distillations, may, if you will, be rectified again. For this purpose you must mix it with fresh lime, and distill it as you did the clear oil. A portion of this also will be attenuated, and come over first. Thus all the fat oil may be subtilized by the action of fire ; an absolutely charred black part excepted, that remains fixed, and appears susceptible of no change, but by burning it in the open air, and thereby reducing it to ashes, from which a little fixed alkali may be obtained. In this fixed part of the oil the acid and earthy parts are combined therewith, in a greater proportion than they ought to be in pure oil.

The portion of oil that hath become light and thin is nothing but the purest oily parts separated from the gross acids, and from a certain quantity of earth, which made it thick and heavy. This oil resembles the essential oils in lightness, fluidity, and a penetrating agreeable odour : it dissolves in spirit of wine. We shall have occasion in the sequel to enlarge further on the qualities of the several sorts of oils, and their solubility in spirit of wine, when we come to treat of ardent spirits and of æther.

P R O C E S S II.

To combine Fat Oils with Acids. The decomposition of this combination.

PUT any Fat Oil whatever into a glass basin, and set it in a sand-bath very moderately heated. Pour on this oil an equal quantity of concentrated oil of vitriol, which will immediately dissolve it with violence; a considerable ebullition and effervescence will arise, attended with great heat, and a prodigious quantity of black, thick vapours, in which may be easily perceived the smell of burnt oil, together with that of a sulphureous acid. The mixture will become of a deep red black, and thick. Stir it with a small stick, till you observe that all is quiet.

O B S E R V A T I O N S.

The vitriolic and nitrous acids unite with fat oils, and dissolve them with violence; but these acids must be sufficiently strong and concentrated, otherwise they will not act upon the oils. The vitriolic acid, in particular, dissolves them pretty thoroughly. If hot water be poured on the mixture described in our process, this water will become cloudy and milky, by dissolving some of it: so that oils may be rendered soluble in water by the means of acids. Spirit of wine, which doth not attack fat oils in their natural state, unites perfectly with them, and makes a clear limpid solution of them, when they are thus combined with acids.

The acids also suffer a considerable alteration by contracting an union with oils. They become much milder, and lose almost all their strength. If the mixture described in the process be distilled, there

will come over a great quantity of an empyreumatic acidulated phlegm, that smells strong of sulphureous spirit ; an oil thinner than the original saponaceous mixture ; a weak oily acid, and a very thick, black oil. If the fire be made very strong, when the oil ceases to rise, it sometimes happens, that a little sulphur sublimes into the neck of the retort.

By this analysis it appears that the strong concentrated acid, which was an ingredient in the combination, is not now to be found. The vitriolic acid hath changed its nature, and is considerably weakened by the union it hath contracted with the principles of the oil. The aqueous part of this latter substance weakens the other, and loads it with phlegm ; the inflammable part thereof renders it sulphureous, and even converts it into sulphur.

Hence it follows that some part of the oil is decomposed, by the union it contracts with the vitriolic acid : for its phlogiston and its aqueous principle cannot be disunited, so as to form a sulphureous spirit, or an actual sulphur, and an aqueous acid, without the decomposition of a certain quantity of the oil, in proportion to the two disjoined principles. Another portion of the oil remains united with the vitriolic acid, without suffering any decomposition, and communicates to that portion of the acid, with which it is so combined, a somewhat saponaceous quality, which makes it resemble the vegetable acids

Thus we see, that, when the vitriolic acid and a fat oil are combined together, they both suffer considerable changes ; the acid by the new alliances into which it enters, and the oil by the decomposition it undergoes. In consequence hereof a much smaller quantity of oil is obtained, by decomposing this combination, than was at first put in.

If the oil abstracted by distillation be combined again with a fresh quantity of the concentrated acid,

cid, the same effects will again follow ; and by this means any quantity of oil at pleasure may be entirely decomposed. This single experiment affords an evident proof of many important truths advanced in our Elements of the Theory.

Spirit of nitre likewise dissolves expressed oils. With oil of olives it forms a white paste, resembling a fine pomatum. This compound is perfectly soluble in spirit of wine. The acid must be very strong and smoking to unite with this, or with any other fat oil : but it dissolves some of them with more rapidity than others ; in which number is the oil of walnuts. It acts on these oils with so much vehemence that it burns them, in some measure, making them black and thick.

P R O C E S S III.

To combine Fat Oils with Fixed Alkalis. Hard and Soft Soap. The decomposition of Soap.

TAKE a lixivium of alicant kelp made more caustic by lime, as we shall shew when we come to speak of alkalis. Evaporate this lye till it be capable of bearing a new-laid egg. Divide it into two parts ; and to one of these put just water enough to weaken it so, that a new-laid egg will not swim in it, but fall to the bottom. With the lye thus weakened mix an equal quantity of fresh-drawn olive oil. Stir and agitate the mixture well, till it become very white. Set it over a gentle fire, and continue stirring it incessantly, that the two ingredients of which it is compounded may gradually combine together, as part of the water evaporates. When you perceive they begin to unite, pour into the mixture thrice as much of the first strong lye as you took of olive oil. Continue the coction with a gentle fire, always stirring the

matter, till it become so thick that a drop of it fixes, as it cools, into the consistence that soap ought to have. By dissolving a little of the soap in water, you will discover whether or no it contains more oil than ought to be in the composition. If it dissolve therein wholly and perfectly, without the appearance of the least little drop of oil, floating on the water, it is a sign that it doth not contain too much oil. If, on the contrary, you perceive any of these little globules, you must pour into the vessel, containing your matter, a little more of the strong lye, to absorb the redundant oil. If there be too much of the alkali, it may be discovered by the taste. If the soap leave on your tongue the sensation of the alkaline salt, and produce an urinous savour, it is a sign that there is too much salt in proportion to the oil. In this case a little oil must be added to the mixture, to saturate the superabundant alkali. An excess in the quantity of alkali discovers itself likewise by the soap's growing moist in the air, on being exposed to it for some time.

OBSERVATIONS.

Fixed alkalis, even when resolved into a liquor, that is, when loaded with much water, unite easily with fat oils, as appears from the experiment just recited, and require but a moderate heat to perfect that union. This combination may even be completely effected without the aid of fire, and by the heat of the sun only, provided sufficient time be allowed for that purpose; as Mr. Geoffroy found upon trial. It only requires the mixture of the oil and alkali to be kept five or six days in digestion, and stirred from time to time. A lixivium of pure alkali, not acuated by lime, may also be used to make soap: but it is observed that the combination succeeds better, and that the alkali unites sooner and

and more perfectly with the oil, when it is sharpened by lime.

The oil is first mixed with a weaker and more aqueous lye, to the end that the combination may not take place too hastily, but that all the particles of the two substances to be compounded together may unite equally. But as soon as the alkali begins to dissolve the oil gradually and quietly, the dissolution may then be accelerated; and that is done by adding the remaining lye, which is stronger and less diluted than the other.

Soap made with olive oil is white, hard, and hath not a very disagreeable smell: but as that oil is dear, others, even the fat and oils of animals, are sometimes substituted for it. The soaps made with most of these other matters are neither so hard, nor so white, as that made of olive oil: they are called *soft soaps*.

Oils thus associated with fixed alkalis are by that means rendered soluble in water; because the alkaline salts, having a great affinity with water, communicate part thereof to the oils with which they are now incorporated. Yet the oil is not for all that rendered thoroughly miscible with water, or perfectly soluble therein; for the water in which soap is dissolved hath always a milky cast: now there is no other criterion of a perfect solution but transparency.

Alkalis also lose part of their affinity with water, by the union they thus contract with oils: for, when the combination is properly made, they no longer attract the moisture of the air, nor doth water dissolve them in such quantities as before. The composition of soap is plainly a saturation of an alkali with an oil; and, in order to make perfect soap, we are forced, as was said in the process, to grope, in a manner, by repeated trials, for this point of saturation; just as, when we prepare a neutral salt by saturating an alkali with an acid. The u-

nion which the oil contracts with the alkali makes it lose, in part, the readiness with which it naturally takes fire; because the salt is not inflammable: the water also, which enters, in pretty considerable quantities, into the composition of soap, as we shall presently see, contributes a good deal to hinder the accension of the oil.

Soap may be decomposed either by distilling it, or by mixing it with some substance that hath a greater affinity than oil with alkalis.

If we decompose it by distillation, a phlegm, or transparent spirit, of a somewhat yellowish colour, first comes over. This liquor is the aqueous part of the soap, quickened by a little of its alkali, which gives it an acrid taste. It is followed by a red oil, which at first is pretty thin and limpid, but thickens as the distillation advances, grows black, and has a very disagreeable empyreumatic smell. This oil is soluble in spirit of wine.

When the distillation is finished, that is, when the retort being kept red-hot for some time will discharge no more, there is left in it a saline mass; which is the alkali of the soap, cruisted over with some of the most fixed parts of the oil, that are charred to a coal. This salt may be restored to the same degree of purity it had before its combination with the oil, by calcining it in a crucible with a naked fire, that may consume this burnt part of the oil, and reduce it to ashes.

It is plain that the oil contained in soap is affected by distillation, much in the same manner as that which we mixed with lime and distilled.

Mr. Geoffroy, by analysing soap with care, discovered that two ounces thereof contain ninety six grains of salt of kelp, freed from all oil and moisture; or two drams and forty-eight grains of that salt, as it is used in manufacturing soap; that is, containing water enough to make it crystallize; one ounce three drams twenty grains of olive oil; and about two drams four grains of water.

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As acids have a greater affinity than any other substance with alkalis, they may be very effectually employed to decompose soap.

If you propose to decompose soap by means thereof, you must first dissolve it in a sufficient quantity of water. Mr. Geoffroy, who made this experiment likewise, dissolved two ounces thereof in about three gallons of warm water, and to the solution added oil of vitriol, which he let fall into it drop by drop. Every time a drop of acid falls into it, a *coagulum* is formed in the liquor. The vessel in which the solution is contained must then be shaken, that the acid may equally attack all the alkali diffused in it. When no new coagulation is produced by a drop of the acid, it is a sign you have added enough. The liquor then begins to grow clear: and if another quart of water be added, in order to facilitate the separation of the oily particles, you will see them rise and unite together on the surface of the liquor.

This is a pure, clear, true olive oil, hath its taste, its smell, and, like it, is fluid in warm weather, and becomes fixed by cold. Yet it differs in some respects from that which never hath been united with an alkali in order to form a soap; for it burns more vividly and more rapidly, and is soluble in spirit of wine. We shall account for these differences when we come to treat of ardent spirits.

Not only the vitriolic acid, but all others even those obtained from vegetables, are capable of decomposing soap, and separating the oil from the alkali. In the liquor wherein soap is thus decomposed is found a neutral salt, consisting of the acid made use of, united with the alkali of the soap. If the vitriolic acid be used, you will have a glauber's salt; a quadrangular nitre, if the nitrous acid be used; and so of the rest.

The facility with which acids decompose soap is the reason that no water, but what is very pure, will dissolve it, or is fit to be used in washing with it.

Water

Water that doth not dissolve soap well is usually called *hard water*. Such waters contain a certain quantity of saline matters, washed out of the earths through which they pass. The hardness of water is generally occasioned by selenetic particles.

The hardness of all the well-water in and about Paris is owing to a considerable quantity of selenitic gypsum with which the soil abounds. The selenites, we know, are neutral salts consisting of the vitriolic acid united with an earthy basis. If therefore soap be put into water in which a salt of this kind is dissolved, it is evident that the vitriolic acid in the selenities, having a greater affinity with the fixed alkali of the soap than with its own earthy basis, will quit the latter to unite with the former; and thus the soap will be decomposed instead of being dissolved. Accordingly we see, that, when we attempt to dissolve soap in our well-water, the surface of the liquor is in a short time covered with a fat oily pellicle. However, this decomposition of soap is not complete; at least but a small part of it is perfectly decomposed; because the great quantity of selenities, with which the water is impregnated, hinders the soap from mixing so thoroughly with it, as is requisite to produce a total decomposition thereof.

All mineral waters are likewise hard, with regard to soap; for as most of them owe their virtues to the efflorescences they have washed off, from pyrites that have grown hot and begun to be decomposed they are impregnated with the saline matters produced by pyrites in that state: that is, with aluminous, vitriolic, and sulphureous substances, which have the same effect on soap as the selenites have.

Mineral waters containing neutral salts only, such as sea-salt, Epsom-salt, Glauber's salt, are nevertheless hard with regard to soap, though the acids of those salts, being united with fixed alkalis, are in-

incapable of decomposing it. The reason is, that those neutral salts are more soluble in water than soap is ; so much indeed as even to exclude it : because each of the two principles that composed them hath a very great affinity with water ; whereas only one of the principles of soap, namely its alkali, hath that affinity ; the other, to wit, the oily principle, having none at all. Thus water impregnated with an acid, or with any neutral salt, is hard with regard to soap, and incapable of dissolving it ; and hence it follows that soap is a sort of touchstone for trying the purity of water.

Wine dissolves soap ; but imperfectly, because it contains an acid or tartarous part. Spirit of wine also dissolves it : but neither is this dissolution perfect ; because it contains too little water : for its spirituous part can dissolve nothing but the oil of the soap ; and the alkali is not at all, or at least in a very small quantity, soluble in this menstruum. The true solvent of soap is therefore a liquor that is partly spirituous, partly aqueous, and not acid.

Brandy has these qualities : and accordingly it is the solvent that unites best with the soap, dissolves the greatest quantity, and makes the most limpid solution thereof. Yet even this solution hath something of a milky cast, occasioned by its not being entirely free from an acid, or the tartarous principle. This fault may be easily corrected, by mixing with it a little alkali to absorb the acid. A dram of crystallized salt of kelp mixed with three ounces and a half of good brandy, renders it capable of dissolving an ounce and two drams of good hard soap, into a perfectly limpid liquor. This experiment also we owe to Mr. Geoffroy.

Some years ago it was discovered that soap might be used with great success in medicine, and that it possesses the property of dissolving the stony concretions that form in several parts of the body, particularly in the kidneys and bladder. Soap is the
basis

basis of the composition known by the name of *Mrs. Stephen's remedy*; and in this one ingredient its whole virtue resides.

From what hath been said on the nature of this compound, as well as on the cause and phenomena of its dissolution, it plainly appears to be of the last consequence, in administering it to a patient, that his constitution be considered, and a proper regimen ordered. All acids should be absolutely forbid him; as we know they hinder the soap from dissolving, and decompose it: and if the patient have any acidities in the first passages, matters capable of neutralizing them should be prescribed him; as prepared crabs eyes, and other absorbents known in medicine: In such cases those with which the soap is compounded in *Mrs. Stephen's remedy* may be of use.

P R O C E S S IV.

To combine Fat Oils with Sulphur.

PUT any fat oil whatever into an earthen vessel; add to it about the fourth part of its weight of flower of sulphur, and set the vessel in a furnace, with lighted coals under it. When the oil hath acquired a certain degree of heat, the sulphur will melt, and you will see it fall immediately to the bottom of the oil, in the form of a very red fluid. The two substances will remain thus separated, without mixing together, while the heat is no greater than is necessary to keep the sulphur in fusion. Increase it therefore; but slowly and with circumspection, lest the matter take fire. When the oil begins to smoke, the two liquors will begin to mix and look turbid: at last they will unite so as to appear one homogeneous whole. If you keep up the heat so that the mixture shall always continue

tinue smoking and ready to boil, you may add more sulphur, which will perfectly incorporate with it: and thus may a pretty considerable quantity thereof be introduced into this composition.

OBSERVATIONS.

The phlogiston and the vitriolic acid have each an affinity with oils. It is not therefore surprising that sulphur, which is a compound of these two substances, should be soluble in oily matters. Yet it is remarkable that essential oils, which are much thinner than the fat oils, dissolve sulphur with much more difficulty; as will be shewn when we come to treat of those oils, and that spirit of wine, which contains an exceeding subtile oil, doth not act upon sulphur at all.

Oil, by contracting an union with sulphur, produces a considerable alteration in that mineral: a phenomenon so much the more surprising, that we know it to be, in some sort, unalterable by any other solvent, of what kind soever, add that its nature admits of no change but by burning. We shall say more on this subject under the head of essential oils.

PROCESS V.

To combine Fat Oils with Lead, and the Calxes of Lead, The Basis of Plaisters. The Decomposition of this Combination.

INTO an earthen vessel put granulated lead, litharge, ceruse, or minium; and pour thereon twice its weight of any fat oil whatever. If you set the vessel over a brisk fire, the lead at bottom will melt before the oil begin to boil. When it boils, stir the matter with a stick: the lead or the calx

calx of lead will gradually disappear, and at last be totally dissolved by the oil, to which it will give a very thick consistence.

O R S E R V A T I O N S.

Fat oils dissolve not only lead, but its calxes also: nay, they dissolve the latter more readily than lead in substance; probably because they are more divided. The result of a combination of these matters is a thick, tenacious mass, that grows in some degree hard in the cold, and soft by heat. This composition is known in pharmacy by the name of *plaster*. It is made up with several drugs into plasters, which partake of the virtues of those drugs; so that it is the basis of almost all plasters.

Lead itself is seldom used to make plasters: ceruse, litharge, or minium are preferred to it; because these matters unite, as hath been said, more readily and more easily with oils.

It sometimes happens that the oil is burnt in the operation, and that the calx of lead is partly re-fuscitated: and this gives the plaster a black colour, which however it ought not to have. This accident is occasioned by an excess of heat: and as it is very difficult to keep the oil and the lead in the proper degree of heat, seeing both these matters are apt to grow very hot, it hath been contrived to put into the vessel, in which the coction is to be performed, a pretty large quantity of water; which being susceptible only of a much smaller and a certain degree of heat, that is constantly the same when it boils, procures the advantage of having the composition very uniform, and very white.

It is necessary to stir the mixture incessantly, in order to prevent the burning of the combined oil and lead; which, as they unite, sink in the water by their greater weight. If the water happen to be
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wasted before the oil hath dissolved all the lead, or before the plaister hath acquired a proper degree of consistence, you must remove the vessel from the fire, and let the mixture cool, before you add more: for if this precaution be neglected, the heat of the matter, which is now much greater than that of boiling water, will occasion a considerable explosion and extravasation thereof, though the water poured into it be as hot as possible.

The combination of fat oil with a calx of lead may be considered as a sort of metallic soap, having a metalline calx, instead of a fixed alkali, for its basis. Mr. Geoffroy hath observed that if a pound of litharge, rubbed very fine and well washed, be incorporated with two pounds of olive oil, in the same manner as plaister is made, keeping water enough in the vessel to hinder the mixture from burning, there rises a smoke, while the oil is uniting with the calx of lead, smelling much like that which rises from soap.

The oil may be separated from the calx of lead, by the methods used to separate it from a fixed alkali: and when it is so separated, it hath the same properties as that separated from common soap.

This species of metallic soap, formed by the union of a fat oil with the calx of lead, is not soluble in water, and communicates nothing to it but a greasy taste. Therefore, if you would decompose it by the means of an acid, you must pour that acid immediately on the compound. The acid will attack and dissolve the calx of lead; and the oil, being thus set at liberty, will rise clear and limpid to the surface of the acid liquor. Distilled vinegar effects this separation better than any other acid, because it is the true solvent of lead.



C H A P. IV.

OF THE SUBSTANCES OBTAINED FROM VEGETABLES WITH A DEGREE OF HEAT NOT EXCEEDING THAT OF BOILING WATER.

P R O C E S S I.

To obtain from Plants, by distilling them with the mean degree of heat between freezing and boiling water, a liquor impregnated with their Principle of Odour.

IN the morning, before sun-rise, gather the plant from which you design to extract its odoriferous water. Chuse the plant in its full vigour, perfectly sound, and free from all adventitious matters, except dew. Put this plant, without squeezing it, into the body of a tinned copper alembic, and set it in a water-bath. Fit on its head, and to the nose thereof lute a glass receiver with wet bladder.

Warm the bath to the mean degree between freezing and boiling water. You will see a liquor distill and fall drop by drop into the receiver. Continue the distillation with this degree of heat, till no more drops fall from the nose of the alembic. Then unlute the vessels; and if you have not as much liquor as you want, take out of the cucurbit the plant already distilled, and put a fresh one in its place. Distill as before, and go on thus till you have a sufficient quantity of odoriferous liquor. Put it into a bottle; stop it close; and set it in a cool place.

O B S E R-

OBSERVATIONS.

The liquor obtained from plants, with the degree of heat here prescribed, consists of the dew that was on the plant, and some of the phlegm of the plant itself, together with its odorous principle. Mr. Boerhaave, who examined this odoriferous part of plants with great care, calls it the *spiritus rector*. The nature of this spirit is not yet thoroughly ascertained; because it is so very volatile, that it cannot easily be subjected to the experiments that are necessary to analyse it, and to discover all its properties. If the bottle containing the liquor, which may be considered as the vehicle of this spirit, be not exceeding carefully stopped, it flies quite off: so that in a few days nothing will be found but an insipid inodorous water.

Great part of the virtue of plants resides in this their principle of odour: and to it must be ascribed the most singular and the most wonderful effects we every day see produced by them. Every body knows that a great number of odorous plants affect, in a particular manner, by their scent only, the brain and the *genus nervosum*, of such especially whose nerves are very sensible, and susceptible of the slightest impression; such as hypochondriacal or melancholy men, and hysterical women. The smell of the tuberose, for instance, is capable of throwing such persons into fits, so as to make them drop down, and swoon away. The smell of rue again, which is equally strong and penetrating, but of a different kind, is a specific remedy against the ill effects of the tuberose; and brings those persons to life again, with as quick and as surprising an efficacy, as that by which they were reduced to a state not unlike death. This is Mr. Boerhaave's observation.

The odorous exhalations of plants must be considered as a continual emanation of their *spiritus rector* : but as growing plants are in a condition to repair, every instant, the losses they sustain by this means, as well as by transpiration, it is not surprising that they are not soon exhausted, while they continue in vigour. Those, on the contrary, which we distill, having no such resource, are very soon entirely deprived of this principle.

The separation of the *spiritus rector* from plants, requires but a very gentle heat, equally distant from the freezing point, and from the heat of boiling water. Accordingly the heat of the sun in summer is sufficient to dissipate it almost entirely. This shews why it is dangerous to stay long in fields, or woods, where many noxious plants grow. The virtues of plants residing chiefly in their exhalations, which the heat of the sun encreases considerably, a sort of atmosphere is formed round them, and carried by the air and the wind to very great distances.

For the same reason the air of a country may be rendered salutary and medicinal, by the exhalations of wholesome plants growing therein. From the facility with which the odorous principle of plants evaporates, we learn what care ought to be taken in drying those intended for medical uses, so as to preserve their virtues. They must by no means be exposed to the sun, or laid in a warm place : a cool, dry place, into which the rays of the sun never penetrate, is the properest for drying plants, with as little loss of their virtue as possible.

Though there is reason to believe that every vegetable matter hath a *spiritus rector*, seeing each hath its particular scent, yet this principle is not very perceptible in any but those which have a very manifest odour : and accordingly it is extracted chiefly from aromatic plants, or the most odoriferous

rous parts of plants. I say the most odoriferous parts; because, in most plants and trees, there are generally certain parts, that have a much more sensible, and much stronger scent than the rest. The odour of a plant, or of a tree, hath its principal residence sometimes in the root, sometimes in the leaves, at other times in the bark or wood, and very frequently in the flowers and seeds. Therefore, when you design to extract the principle of odour from a vegetable that is not equally odoriferous in every part, you must chuse those parts that have the most perceptible and strongest scent.

PROCESS II.

To extract the Fat Oils of Plants by Decoction in boiling Water. Cacao-Butter.

POUND or bruise in a marble mortar your vegetable substances, abounding with the fat oil which you intend to extract by decoction: tie them up in a linen cloth: put this packet into a pan, with seven or eight times as much water, and make the water boil. The oil will be separated by the ebullition, and float on the surface of the water. Skim it off carefully with a ladle, and continue boiling till no more oil appear.

OBSERVATIONS.

The heat of boiling water is capable of separating the fat oils from vegetable matters that contain any: but this is to be effected by actual decoction only, and not by distillation; because these oils will not rise in an alembic with the heat of boiling water. We are therefore necessitated to collect them from the surface of the water, as above directed.

ed. By this means a much greater quantity of fat oil may be obtained than by expression alone ; because the degree of heat applied greatly facilitates the separation of the oil. For a convincing proof of this truth, take the remains of any vegetable matters, from which the oil hath been so thoroughly expressed that they would yield no more ; boil them in this manner, and you will obtain a great deal more oil

The water used in this coction generally becomes milky, like an emulsion ; because it contains many oily particles, that are dispersed in it just as in an emulsion. Nevertheless this way of obtaining the fat oils is not generally practised ; because the heat, to which they are exposed in the operation, occasions their being less mild than they naturally are : but it is an excellent method, and indeed the only one that can be employed, for extracting from particular vegetables certain concrete oily matters, in the form of butter or wax ; which matters are no other than fat oils in a fixed state. The cacao yields, by this means, a very mild butter ; and in the same manner is a wax obtained from a certain shrub in America.

The heat of boiling water melts these oily matters, which then ascend to the surface of the liquor, and float on it like other oils. They afterwards fix as they cool, and resume their natural consistence. We shall see in the sequel that they cannot be extracted in a concrete form by distillation, which requires a greater degree of heat than that of boiling water ; because distillation changes their nature, partly decomposes them, and prevents their returning to their proper consistence as they cool.

P R O C E S S III.

To extract the Essential Oils of Plants by distillation with the heat of boiling water. Distilled waters.

PUT into a cucurbit the plant from which you design to extract the essential oil. Add as much water as will fill two thirds of your vessel, and dissolve therein half an ounce of sea-salt for every quart of water you use. To this body fit on an alembic-head, and to the nose thereof lute a receiver, with sized paper, or wet bladder. Set it in a furnace, and let the whole digest together, in a very gentle warmth, for twenty four hours.

This being done, light a wood-fire under your vessel, brisk enough to make the water in it boil immediately. Then slacken your fire, and leave it just strong enough to keep the water simmering. There will come over into the receiver a liquor of a whitish colour, somewhat milky; on the surface of which, or at the bottom, will be found an oil, which is the essential oil of the vegetable you put into the cucurbit. Continue your distillation with the same degree of heat, till you perceive the liquor come off clear, and unaccompanied with any oil.

When the distillation is finished, unlute the receiver: and, if the essential oil be of that sort that is lighter than water, fill the vessel up to the top with water. On this occasion a long necked matrass should be used for a receiver: that the oil which floats on the water may collect together in its neck, and rise up to its mouth. Then in the neck of this vessel put the end of a thread of cotton twine, so that the depending part without the vessel may be longer than that in the oil, and the extremity

extremity thereof hang within the mouth of a little phial, just big enough to contain your quantity of oil. The oil will rise along the yarn as in a siphon, filter through it, and fall drop by drop into the little phial. When all the oil is thus come over, stop your little bottle very close, with a cork coated over with a mixture of wax and a little pitch.

If your oil be ponderous, and of the sort that sinks in water, pour the whole contents of the receiver into a glass funnel, the pipe of which must terminate in a very small aperture that may be stopped with your fore-finger. All the oil will be collected in the lower part of the funnel: then remove your finger, and let the oil run out into a little bottle through another small funnel. When you see the water ready to come, stop the pipe of the funnel, and cork the bottle containing your oil.

OBSERVATIONS.

Essential oils, though they all resemble each other in their principal properties, are nevertheless very different in some respects: for which reason almost every one of them requires a particular management, for obtaining it with the greatest advantage possible, both as to quality and quantity.

One of the first things requisite is, to chuse the proper time for distilling the plant, from which you desire to extract the essential oil; because the quantity of oil varies considerably, according to the season of the year, as well as the age of the plant. For example, the most favourable time for obtaining these oils from the leaves of ever-green plants or trees, such as thyme, sage, rosemary, the orange, the bay, the fir, &c. is the end of autumn; because these vegetables contain a great deal more oil at that season than at any other. With regard to annual plants, they must be chosen when in their prime, and just before they begin to decline.

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The time therefore of gathering them is when they begin to flower : and if you want to extract the oil from the flowers themselves, you must pull them just when they are newly blown.

Secondly, it must be observed that the essential oils of plants are, as it were, the chief residence and reservoir of their odorous principle ; that they are to be found wherever that principle exists, and never where it is not : so that what we said concerning the *spiritus rector* of plants is applicable here. It must be remembered that all the parts of some vegetables are odoriferous. Such plants may be put into the alembic all together, and the essential oil distilled from all their parts at once. But others, and indeed the greatest number, have no odour, or at least none that is very perceptible, except in some particular parts ; as in their leaves, flowers, roots, or seeds : therefore when you want to have the essential oil of such a plant, you must chuse that part in which the odour resides. The sense of smelling must be the artist's principal guide on this occasion.

Thirdly, all vegetables, and all the parts of vegetables, have not the same texture : some are hard and compact, as woods, barks, and some roots ; others are tender and succulent, as most annual plants and some fruits. For this reason they must be differently prepared for distillation. It may be laid down as a general rule, that, the closer and more compact their texture is, the more they require to be opened and divided, either by comminuting them into small particles, or by digesting them a considerable time in water acuated with salt.

Fourthly, though all essential oils be capable of rising in distillation with the heat of boiling water, yet they have not all an equal degree of levity and weight on the contrary, they vary exceedingly in this respect : some, as for instance those of all our European aromatics, being lighter than water, so that

that they always float on it's surface ; whereas others, such as those of cloves, saffrafras, &c. which are Indian aromatics, are heavier than water, and always sink in it by their specific gravity. These differences therefore require different methods of distillation. It is proper, for example, to make use of a low alembic in distilling such essential oils as are heavier than water ; and moreover, to facilitate their separation, by applying a degree of heat somewhat stronger than that of boiling water. This is easily done by impregnating the water with a proper quantity of sea salt, or the vitriolic acid ; for, the more saline matters are contained in water, the more will the degree of heat it acquires, by being brought to boil, exceed that of pure boiling water.

Fifthly ; Essential oils differ from one another in point of fluidity. Some are as thin and as fluid as spirit of wine : of this number is the essential oil of turpentine. Others again are thick, and even congeal as they cool : such, for instance, is the oil of roses. In distilling oils of this latter sort, care must be taken that the spout of the alembic head do not grow too cold, but be kept always in such a degree of warmth, as may prevent the oil from fixing in it, and stopping it up ; which would interrupt the distillation, and might also occasion some other more considerable inconveniences, of which we shall take notice presently.

From what hath been said it appears that the distillation of essential oils cannot be regulated by any one general rule ; but that the manner of operating must be a little varied, according to the nature of the oil to be distilled, and to that of the vegetable from which it is to be drawn.

The time of day, fittest to gather plants for this distillation, is the morning before sun-rise because the coolness of the night hath shut all their pores, and concentrated their odour : whereas in the even-

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ing, after the plants have been exposed all day to the heat of the sun, their odorous principle is in a great measure dissipated, and they are left almost quite exhausted of it. Now, the more of the odorous principle the plants contain, the more essential oil will they yield, and the more virtue will that oil have.

Plants fresh gathered, and as yet full of moisture, do not yield so much oil in distillation as they do when dried; because the oily particles in a very moist plant are more diffused, and even separated from each other, by the interposition of the aqueous parts: whence it comes to pass that, in distillation, they ascend in a state of separation from each other; so that being dispersed through the water they give it a milky colour, like that of an emulsion; and cannot unite together but in small quantities, which hinders their being easily separated from the water.

This inconvenience doth not happen, or at least is considerably less, when the greatest part of the humidity of the plant is evaporated by desiccation: for the oily particles, being thus delivered from the intervening aqueous parts, which keep them separated from each other, are brought nearer together, unite, and form little visible globules of oil, which easily emerge from the water employed in the distillation. But, in drying plants from which the essential oil is to be extracted, great care must be taken that they be neither exposed to the sun, nor laid in a warm place; because the heat would carry off part of their odour, and even, from some plants, a pretty considerable quantity of their essential oil,

Plants of a loose texture, that easily give out their essential oils, need not be comminuted, or macerated in water with salt. But this method must unavoidably be taken with such as are hard, and do not readily part with their oil. Woods
barks,

barks, roots, for instance, must be first rasped, then set to macerate in water impregnated with salt, as before directed; and this sometimes for several weeks before they be distilled.

On this occasion salt procures three different advantages. In the first place, it prevents the matters, that must stand in maceration for some time, from running into fermentation: an inconvenience that would considerably diminish the quantity of essential oil, or perhaps rob us of the whole, by converting it into an ardent spirit, if the fermentation were spirituous; or into a volatile alkali, if it went on to the last stage, and as far as putrefaction. In the next place, it acuates the water, and renders it more capable of penetrating and properly dividing, during the maceration, the texture of the plant which requires to be thus prepared. Lastly, it adds a little to the heat of the boiling water, and so promotes the ascent of the heaviest oils.

Nevertheless, when you find it necessary, for the reasons assigned above, to mix salt with the water to be employed in distilling your essential oil, you must be cautious of putting in too much. You will indeed obtain, by means thereof, much more oil than if you distilled it without salt: but, as a great quantity of salt will make the water acquire a much greater degree of heat, than that of pure boiling water, a good deal of the heavy oil of the vegetable will be raised by such a heat, mix with the essential oil, deprave it, and make it like those that are adulterated with a mixture of some heterogeneous oil, as will be afterwards shewn.

When every thing is prepared for distillation, it is proper, as directed in the process, to apply at once a flaming fire, brisk enough to make the liquor boil immediately: for, if the water be kept long heating before it be made to boil, the essential oil, which cannot rise without the heat of boiling water, will, by a less degree of heat, be only agitated, dashed about every way, and churned as it were;

were; by which means it will be divided into very minute particles, and dispersed in the water, which will thence acquire a milky colour; and consequently we shall fall into the inconvenience that was pointed out above, as happening when we distil plants without having dried them, and while they are loaded with all the moisture and sap that was in them when fresh gathered.

When the wather in the cucurbit, boils it will be known by the noise that boiling water usually makes, which is produced by the numerous bubbles that rise and burst on its surface. The spout of the alembic is then so hot, that a man cannot lay his finger on it, without such a sensation of burning heat as is not to be endured. With this degree of heat the water distills in drops, which succeed each others so fast, that they seem to form a continued small stream; and this water is replete with much essential oil.

And now it is proper to weaken the fire considerably, so as to leave it but just strong enough to keep the liquor gently boiling; for if the distillation be urged too precipitately, the aqueous and oily vapours, being forcibly hurried up by two great a heat, may carry along with them some parts of the plant, which may stick in the spout, stop it up, and endanger the bursting of the vessel, or at least the forcing off its head, by the exceedingly rarefied particles of water, oil, and air, all striving to escape at the same time; and these burning hot vapours, being discharged with impetuosity, may not only scald the operator, but injure his lungs.

In such distillations it is of consequence to keep constantly cooling the head of the alembic, by frequently renewing the water in the refrigeratory, in order to facilitate the condensation of the oily particles. The water in the cooler ought to be renewed when it begins to smoke very perceptibly.

Whatever care be taken to save as much of the
VOL. II. Z oil

oil as possible, and to prevent its being left dispersed in the water, yet some loss of this kind cannot be totally avoided: and thus the water that rises in distilling the oil is always more or less milky, and strongly scented, even after it is separated from the essential oil. Yet this portion of the oil and of the odorous principle, which is retained by the water employed in such distillation, is not therefore lost: the water impregnated with these principles partakes of the properties of the plant from which the essential oil was drawn, and may be used medicinally: it is known in pharmacy by the title of the *distilled water* of the plant.

The same water may be used again, with advantage, in distilling the essential oil of a fresh plant of the same sort; because the oily and odorous particles, with which it is impregnated, joining with those afforded by the fresh plant form larger *molecules*, capable of uniting more easily and emerging better from the water; and consequently they increase the quantity of oil. Thus the same water may be always employed in new distillations; and, the oftener it is used, with the greater advantage may it be used again.

After all the essential oil is risen, if the distillation be continued, and the receiver changed, the liquor that will then come off will not be milky, but limpid. It will have no odour at all of the plant, but a kind of sourish smell; and indeed it is a part of the acid of the vegetable in the still, which is elevated by the heat of boiling water, after all the essential oil is come over.

If you intend to keep the distilled water which hath served as a vehicle to the essential oil, and design it for medicinal use, great care must be taken to stop the distillation before this acid phlegm begin to rise: for, if it should mix with the distilled water it would spoil it, and hinder it from keeping; probably

probably because it contains some mucilaginous parts, which are apt to putrify.

PROCESS IV.

To extract the Essential Oils of Plants by distillation per descensum.

Reduce to a powder, or a paste, the vegetable substances from which you intend to extract the essential oil by the method proposed. Lay this matter about half an inch thick on a fine, close, linen cloth. If it be dry and hard, expose the cloth containing it to the steam of boiling water, till the matter become moist and soft. Then lay the cloth, with its contents, over the mouth of a very tall cylindrical glass vessel, which is to do the office of a receiver in this distillation; and, by means of a piece of small pack-thread, fasten down the extremities of the cloth, by winding the thread several times over them and round the vessel; in such a manner, however, that the cloth be not tight, but may yield to a small weight, and sink about five or six lines deep into the vessel over which it is fastened. Set this recipient in a larger vessel, containing so much cold water as will reach half way up the cylindrical vessel; which, having little in it but air, must be ballasted with as much lead as will sink it to the bottom of the water.

On the cloth containing the substance to be distilled set a flat pan of iron or copper, about five or six lines deep, that may just fit the mouth of the glass vessel over which the cloth is fastened, so as to shut it quite close. Fill this pan with hot ashes, and on these lay some live coals. Soon after this you will see vapours descend from the cloth, which will fill the recipient, and drops of liquor will be formed on the underside of the cloth, from whence

they will fall into the vessel. Keep up an equal gentle heat, till you perceive nothing more discharged. Then uncover the recipient: you will find in it two distinct liquors; one of which is the phlegm, and the other the essential oil of the substance distilled.

OBSERVATIONS.

The apparatus for distilling above described is very convenient, when we have not the vessels necessary for distilling with water, or when we want to obtain the essential oil of any vegetable substance in much time. The aqueous and oily parts of the substances distilled in this manner, being rarefied by the heat of the fire placed over them, cannot ascend upwards, because they are close confined on that side; and moreover, the fire which rarefies them possessing all the upper part of the vessel in which they are contained, they are forced to fly from it to the place which most favours their condensation: and this determines them to descend in the recipient, where they meet with a coolness that condenses and fixes them. It was with a view to promote this condensation, that we ordered the lower part of the recipient to be sunk in cold water.

Cloves are one of those substances whose essential oil is best obtained by this method. In the same way also may be drawn the essential oil of lemon-peel, citron-peel, orange-peel, nutmegs, and several other vegetable substances: but you must be cautious of applying too strong a heat; for in that case the oil, instead of being white and limpid, acquires a red, dark brown, blackish colour, is burnt, and smells of empyreuma: and, on the other hand, if you do not apply a proper degree of heat, you will scarce get any oil at all. It is the surest, and therefore the best, way to distill these oils with water

ter in an alembic. And indeed the distillation *per descensum* is seldom used, but out of curiosity to try its effect, or on such pressing occasions as allow no choice.

PROCESS V.

Infusions, Decoctions, and Extracts of Plants.

MAKE some water boiling-hot, and then take it off the fire. When it ceases to boil, pour it on the plant of which you desire to have the infusion: taking care there be enough of it to cover the plant entirely. Cover the vessel, and let your plant lye in the hot water for the space of half an hour, or longer if it be of a firm close texture. Then pour off the water by inclination: it will have partly acquired the colour, the smell, the taste, and the virtues of the plant. This liquor is called an *infusion*.

To make the decoction of a vegetable substance, put it into an earthen pan, or into a tinned copper vessel, with a quantity of water sufficient to bear being boiled for several hours, without leaving any part of the plant dry. Boil your plant more or less according to its nature; and then pour off the water by inclination. This water is impregnated with several of the principles of the plant, of which we shall take notice in the following observations.

OBSERVATIONS.

Water, especially when boiling-hot, is capable of dissolving not only all that is purely saline in vegetables, but also a pretty considerable quantity of their oil and of their earth, which, by contracting an union with the saline parts, have formed sapo-

naceous, gummy, and mucilaginous compounds, that are soluble in water. After violent and long continued boiling, therefore, there remains nothing in the plant but the purest oily part, and such as is the most fixed, that is, the most closely united with the earth of the plant. I say the most fixed: for some part of the oily matters, though not soluble in water, may be separated by the action of boiling water, when those matters abound greatly in the vegetable decocted; as we have seen happen to the fat oils of certain vegetable matters: but in that case these oily matters float upon the decoction, and do not constitute a part of it.

From what we have already said, touching the analysis of plants, it seems evident, that, if those decocted be odoriferous and contain an essential oil the decoction will contain none, or at most but very little, of their essential oil, or their odorous principle; seeing we know that these substances cannot be at the heat of boiling water, without being carried off and entirely dissipated by it. Therefore, when we make a decoction of an aromatic plant, containing an essential oil, we may be assured that it will not possess the virtues, either of the odorous part, or of the essential oil, and that it will have none but those of the other more fixed principles of the plant, with which it may be impregnated. The decoction of such a plant perfectly resembles the water left in the cucurbit, after distilling its essential oil. But for those plants in which there are no such volatile parts, or whose virtue doth not reside in those principles, such as astringent and emollient plants, for example, that owe their properties wholly to an earthy salt, or to a mucilage, they are capable of communicating their whole virtue, to the water in which they are infused or decocted.

If, on one hand, the salts of plants render some portion of the principles of those plants soluble in water,

water, such as part of their oil and their earth, which if they were pure would not dissolve therein; on the other hand these principles, being of their own nature indissoluble in water, hinder the salts, by the union they have contracted together, from dissolving in it so easily, so soon, and in such quantities, as if they were pure. This is so true that water, though boiled long and violently, is far from extracting out of plants all those parts that it is capable of dissolving. If, after boiling a plant in water, as directed in the process, this water be poured off, fresh water added, and a second decoction made in the same manner as the first, the water of this latter decoction will, by that means, be almost as strongly impregnated with the principles of the plant as the former was. Mr. Boerhaave was obliged to make twenty successive decoctions of the same plant, to wit, rosemary, before the water came off the plant colourless and insipid; in a word, just as it was before the plant was boiled in it.

Mr. Boerhaave observes that a plant, after having thus given out all that water can dissolve, still retains exactly the same form that it had, before it underwent any of the many boilings necessary to exhaust it; that its colour, from being green at first, becomes brown; and that the plant, which when green is lighter than water, or at least doth not sink in it, is heavier after this operation, and falls to the bottom. This is a proof that the water hath extracted out of the plant its lightest substances, assuming their places itself, and that it hath left nothing but its heaviest principles, namely its fixed oil and its earth. We shall afterwards examine more particularly these remains of plants exhausted by water.

If the infusions and decoctions of plants be filtered, and evaporated in a gentle heat, they become extracts, that may be kept for whole years, especially

cially if they be evaporated to a thick consistence; and better still if they be evaporated to dryness.

From what hath been said concerning the infusions, decoctions, and extracts of plants; it follows 1. that infusions and decoctions of aromatic plants do not furnish a complete extract of those plants; because they do not contain the volatile and odorous parts, in which the principal virtue of such plants usually resides. If therefore you desire to make extracts of such vegetables, that shall have no defect, you must employ their juices drawn by expression, or water impregnated with their principles by the means of trituration, and evaporate the liquor by spreading it over a great number of plates, in order to enlarge its surface, and quicken the evaporation, which must be effected by the heat of the sun alone, or the well-tempered warmth of a stove.

2. It may also be inferred that water alone, aided by the degree of heat it is capable of acquiring by being made to boil, is not sufficient to effect the complete analysis of a plant; since not only some of its principles are still left combined in it, though exhausted as much as it can be by boiling water; but also several of the substances extracted from it by water are compounds of some of the principles of the plant, and susceptible of a much more accurate analysis; as we shall be convinced when we come to examine the effects which a degree of heat superiour to that of boiling water is able to produce on entire plants, on their extracts, and on their remains exhausted as much as they can be by boiling water.

But before we enter on that part of the analysis, it is proper to consider the experiments and combinations that may be made with the principles we have already obtained; in order to discover their nature, and in some measure analyze even them.

Essential

Essential oils in particular deserve to be thus examined.

We also obtain from certain plants, with a degree of heat less than that of boiling water, a volatile alkali, which exists formally in them : but as these plants, when analyzed, yield principles different from those we obtain out of all other vegetable substances, and as they resemble animal matters, we shall refer their analysis to a distinct chapter.



END of VOL. II.